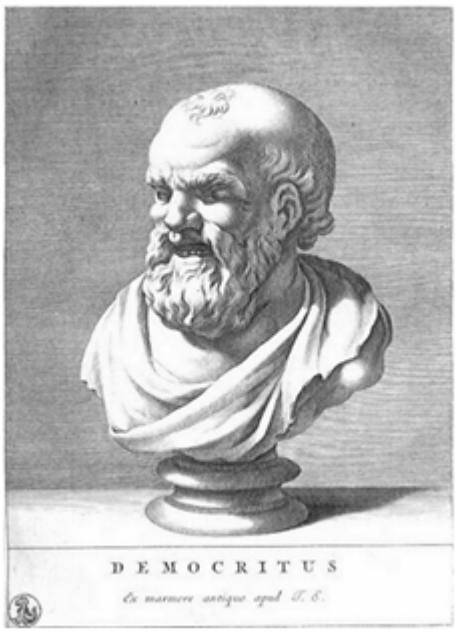
Classification of Matter

Atoms & Elements

Atoms are the smallest units of a substance that still have all the characteristics of that substance.

Atoms

All materials are made up of atoms. There are over 100 different types of atoms, and when grouped together with other atoms of the same type, they make up *elements*, such as copper, tin, and aluminum. Atoms are too small to be seen without being magnified many, many times.

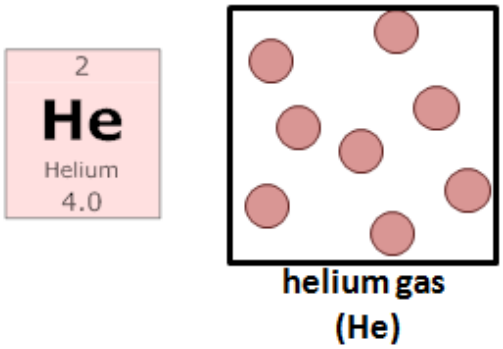


The ancient Greek philosopher Democritus was the first to suggest the existence of atoms. Democritus studied how objects could be cut into tiny pieces. He imagined that if it were possible to keep on cutting an object, he would eventually get to the smallest particle that couldn't be cut any further. He named this particle atom, which means "indivisible" in Greek.

According to Democritus, atoms were the building blocks of matter, and they were indestructible and indivisible. He believed that atoms had different shapes and sizes and were responsible for the different properties of matter. He imagined that white objects were made of smooth atoms while black ones were made of rough atoms. Unfortunately, Democritus's ideas lacked scientific evidence and were rejected by Aristotle, one of the most influential philosophers of his time. However, another scientist, John Dalton, backed Democritus's ideas almost 2,000 years later.

Elements

There are over 100 different kinds of atoms. A substance made up of only one kind of atom is called an **element**. For example, the element helium is made up of only helium atoms, and it is represented by the symbol He on the periodic table of elements.



The element helium is a usually a gas. The particles in helium gas are helium atoms.

Properties of Common Elements

Each element has its own properties, both physical and chemical. Properties can be used to identify elements. For example, knowing what an element looks like can help identify that element. Examples of elements and their appearances are listed in the table below.

Element	Appearance
Carbon	nonmetal, dull black solid or colorless (diamond)
Copper	metal, reddish in color, has a bright, shiny appearance
Gold	metal, yellow in color (when pure) or black, purple, or red when small amounts are present in other metals, shiny
Hydrogen	gas, colorless, lightest gas
Oxygen	nonmetal, colorless as a gas, liquid form is light blue
Silver	metal, white metallic color, shiny

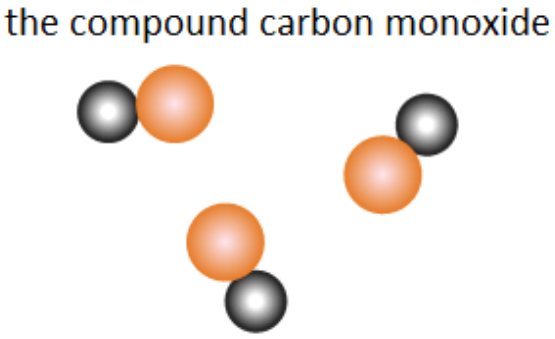
Compounds

A compound is a pure substance that is made up of two or more different types of atoms.

Compounds

When atoms of two or more elements combine to make a compound, the compound has different properties from the original elements. Living organisms and most non-living things are made up of different compounds.

Once the elements in a compound are chemically combined, they do not separate easily, but they can be separated by a chemical reaction. This means that breaking down a compound is a chemical change.



Molecules of the compound carbon monoxide contain one atom of carbon and one atom of oxygen.

Chemical Formulas

A chemical formula involves writing the elements of a compound using their chemical symbols. Chemical formulas use the chemical symbols found on the periodic table.

The combination of two or more elements to form a molecule is designated by writing chemical symbols next to each other. For example, carbon monoxide is written as **CO**. Usually, the element located farthest left on the periodic table is listed first in the formula.

If there is more than one atom of an element in the molecule, the formula uses a **subscript** after the symbol. For example, water is **H_2O**, which means there are two atoms of hydrogen and one atom of oxygen in the molecule. Carbon dioxide is **CO_2**, which means there is one atom of carbon and two atoms of oxygen in the molecule.

The formula of a compound shows the symbols of the elements that are in it. Here are a few examples of compounds and their chemical formulas:

- water (H_2O)
- carbon monoxide (CO)
- potassium chloride (KCl)
- ammonia (NH_3)

To show the number of molecules, a coefficient is used in front of the molecule. For example, three molecules of water are designated as:

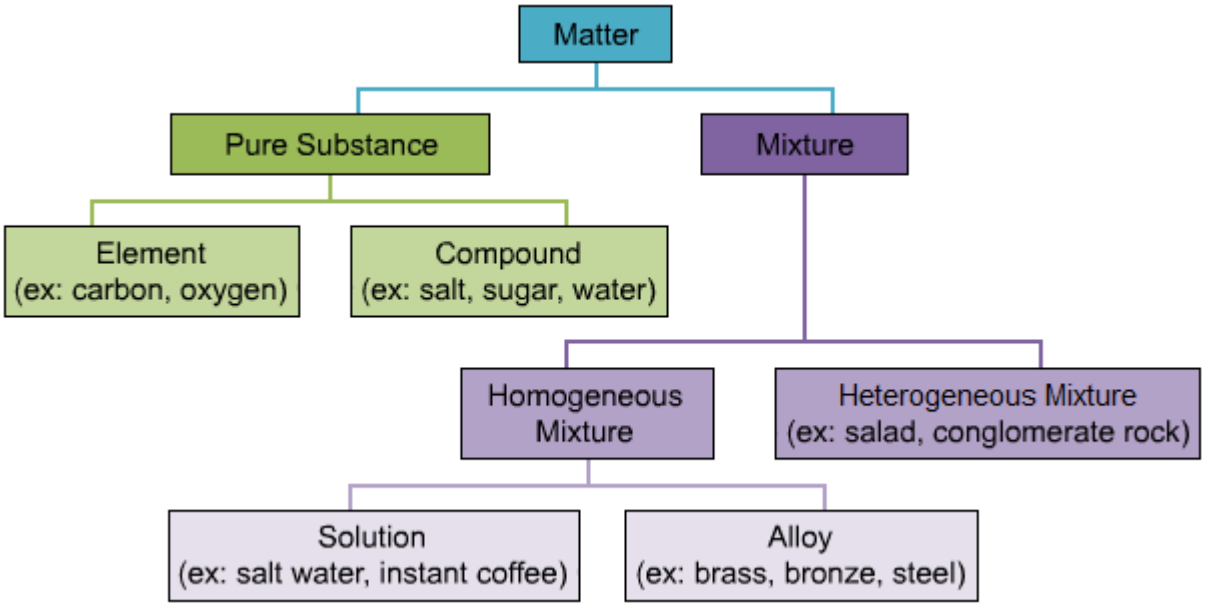
$$3H_2O$$

This means there are a total of 6 **H** atoms and 3 **O** atoms in the combination.

Classification of Matter

*Everything that has mass and volume is made of **matter**.*

Atoms are the building blocks of matter. They cannot be broken down into smaller pieces using chemical reactions or physical change. Various groups of atoms compose all known matter. Matter can be classified into two major categories: pure substances and mixtures.



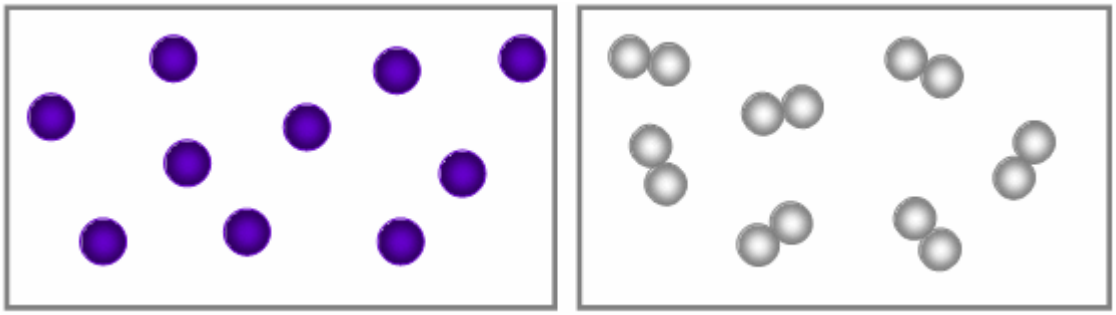
Pure Substances

A pure substance is a type of matter that is made up of only one kind of material. All the particles (i.e., atoms or molecules) in a pure substance are exactly the same, and the same properties are exhibited throughout the substance. There are two main types of pure substances: elements and compounds.

- **Elements**—Elements are the simplest pure substance, because they are made up of only one type of atom. For example, the element carbon is only made up of carbon atoms, and the element zinc is only made up of zinc atoms. The simplest unit of an element that still has the properties of that element is the atom. However, the atoms of some elements are naturally

found bound to other atoms of the same element in two-atom units called *diatomic molecules*.

Today, there are over 100 known elements. These elements are represented by chemical symbols (e.g., C represents carbon and Zn represents zinc) and are listed in order of their atomic numbers on the periodic table.

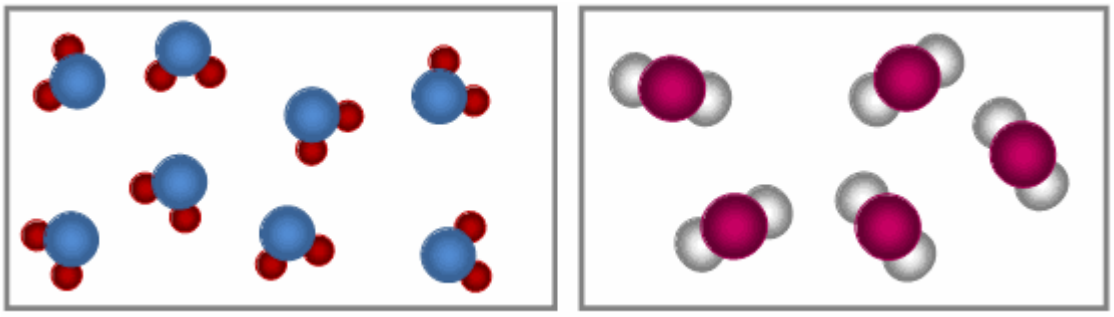


The particle diagrams above model particles of elements. Single atoms of helium gas are shown on the left. Diatomic molecules of nitrogen are shown on the right.

- **Compounds**—Compounds are pure substances that are made up of more than one type of element, chemically combined in a fixed ratio. Depending on the type of compound, its simplest unit may be a molecule or a repeating crystal pattern.

  Although the properties of a compound differ from the properties of the elements that compose it, the molecules of a compound exhibit the same properties as one another. Also, since the elements within a compound are chemically combined, they can only be separated by chemical changes, such as the change caused by electrolysis.

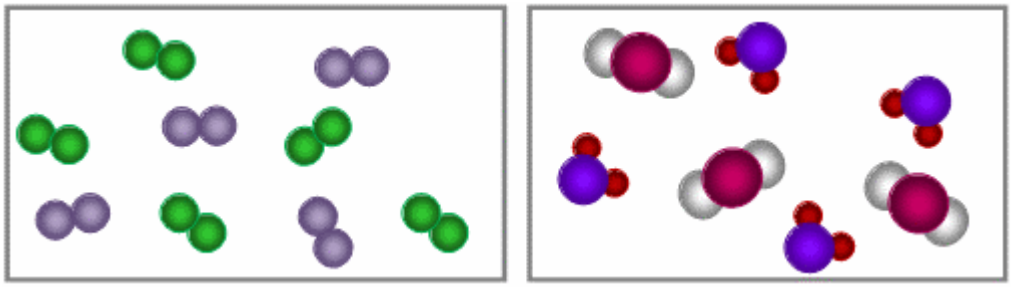
  Compounds have a definite chemical composition that can be identified using a chemical formula. Water (H_2O), salt (sodium chloride, NaCl), and sugar (glucose, $C_6H_{12}O_6$) are all examples of compounds.



The particle diagrams above show compounds. The diagram on the left models molecules of water. The diagram on the right models molecules of carbon dioxide.

Mixtures

Mixtures are made up of two or more substances that are not chemically combined. Because they are not chemically combined, the substances retain their own individual properties of matter, even though they are mixed together. Furthermore, mixtures can be separated by physical means, such as filtration or distillation.



The diagram on the left shows a mixture of diatomic molecules that contain only one type of atom. The diagram on the right shows a mixture of two different compounds whose molecules contain two different types of atoms.

Mixtures can also be divided into two main categories: homogeneous mixtures and heterogeneous mixtures.

- **Homogeneous Mixtures**—A homogeneous mixture is uniform. That is, it has the same properties throughout. *Solutions* and *alloys* are two types of homogeneous mixtures. In a solution, one substance is dissolved into another substance (e.g., salt water, instant coffee). The substance being dissolved is called the *solute*, and the substance doing the dissolving is called the *solvent*. In solutions and alloys, the solute is evenly distributed in the solvent. In *aqueous* solutions, water is the solvent. A solution of a solid in a liquid can generally be separated through the process of vaporization. An alloy is a *solid solution* in which one metal is dissolved into another (e.g., the alloy brass is made of copper and zinc).
- **Heterogeneous Mixtures**—A heterogeneous mixture does not have the same properties throughout. In fact, the substances in a mixture often keep their own separate identities and individual properties. For example, a tossed salad is a heterogeneous mixture, and its properties are not the same throughout. Instead, each part of the salad (e.g., lettuce, tomato, croutons, etc.) keeps its own individual identity and properties.

  Some heterogeneous mixtures are *suspensions*—fluids which contain insoluble solid particles that eventually settle out. A mixture of fine sand and water is a suspension. The pictures below illustrate how, after being mixed with water, sand particles settle to the bottom of the container.

Image is courtesy of NASA.

Some mixtures can be difficult to classify. For example, *colloids* may be classified as a heterogeneous or a homogeneous mixture, depending on the context. In a colloid, solid particles are dispersed in a liquid. While the particles are not dissolved, they may be dispersed well enough that they will not settle out over time as would a suspension. Milk is an example of a colloid. Unlike the components of solutions, the components of a colloid can be separated from one another using a filter if the pores of the filter are sufficiently small.

Mixtures can occur between all phases of matter.

- gas/gas (ex: air)
- gas/liquid (ex: oxygen or carbon dioxide and water)
- liquid/liquid (ex: fruit juice and water)
- solid/liquid (ex: sugar and water)
- solid/solid (ex: metal alloys, such as bronze or steel)

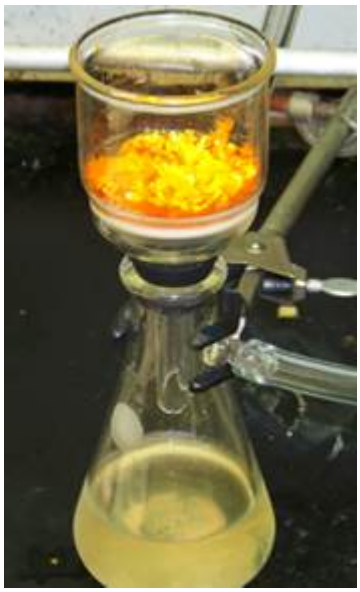
Mixture Separation

A mixture is made up of two or more substances that are not chemically combined. Mixtures can be separated by physical means, so mixture separation is a physical change.

Differences in physical properties such as density, particle size, molecular polarity, solubility, and boiling and freezing points permit physical separation of the components in a mixture. Some of the techniques that can be used to separate mixtures are discussed below.

Filtration

If a mixture is composed of a liquid and an insoluble solid, the mixture can be separated by filtration. During filtration, the mixture is poured through a filter. The solid is trapped by the filter, but the liquid goes through the tiny pores in the filter and can be collected in a container beneath.



Evaporation

If a mixture contains a soluble solid dissolved in a liquid, the two mixture components can be separated by evaporating the liquid off. As the solvent evaporates, the solid solute remains behind as a *residue*.

Heat may or may not be used to accelerate evaporation. If large, pure crystals are desired, evaporation should be allowed to take place over as long a period as possible. However, if crystal size is irrelevant and purity is not a concern, the liquid can be boiled off rapidly. In the image below, an aqueous solution of sodium chloride (salt) was boiled until only a solid salt residue remained in the heating vessel.

Sifting

Sifting, also called *screening* or *sieving*, is a method of filtering solids from one another based on particle size. For example, sifting could be used to remove small pebbles and shells from sand. A sieve or sifter like the one shown above is often used in kitchens to remove lumps from flour.

Study Island

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1. When salt is dissolved in water, the result is a

- **A.** gas
- **B.** compound
- **C.** heterogeneous mixture
- **D.** homogeneous mixture

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2. What is the smallest particle of an element that still retains properties of that element?

- **A.** compound
- **B.** atom
- **C.** mixture
- **D.** molecule

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3. In a _____ mixture, the ingredients are distributed evenly throughout the mixture, while in a _____ mixture, the ingredients are unevenly distributed throughout.

- **A.** heterozygous; homozygous
- **B.** homogeneous; heterogeneous
- **C.** homozygous; heterozygous
- **D.** heterogeneous; homogeneous

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4. Edgar is stranded on an island surrounded by an ocean of salt water. He is thirsty, but he knows that it is a bad idea to drink salt water.

How could Edgar separate the salt out of the salt-water mixture?

- **A.** use chromatography
- **B.** pour the mixture through a screen

- **C.** evaporate off the water
- **D.** use a magnet to attract the salt

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5. An element is made up of

- **A.** a mixture of different types of atoms.
- **B.** only one type of atom.
- **C.** different types of atoms that have been combined chemically.
- **D.** different types of cells.

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6. A mixture is made of two or more materials that

- **A.** cannot be separated by physical means.
- **B.** can only be separated by chemical means.
- **C.** cannot be separated by any means.
- **D.** can be separated by physical means.

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7. What defines a mixture?

- **A.** can be broken down into its basic substances through physical means
- **B.** described by a chemical formula
- **C.** cannot be broken down into simpler substances
- **D.** created through a chemical reaction

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8. The chemical combination of two or more different kinds of atoms in fixed amounts is called a(n)

- **A.** element.
- **B.** orbit.
- **C.** compound.
- **D.** mixture.

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9. Which of the following is true for compounds?

- **A.** They can consist of no more than two types of elements.

○ **B.** They all have the same properties regardless of their elemental composition.
○ **C.** They can be separated into their component elements through physical means.
○ **D.** They can be created by chemical reactions.

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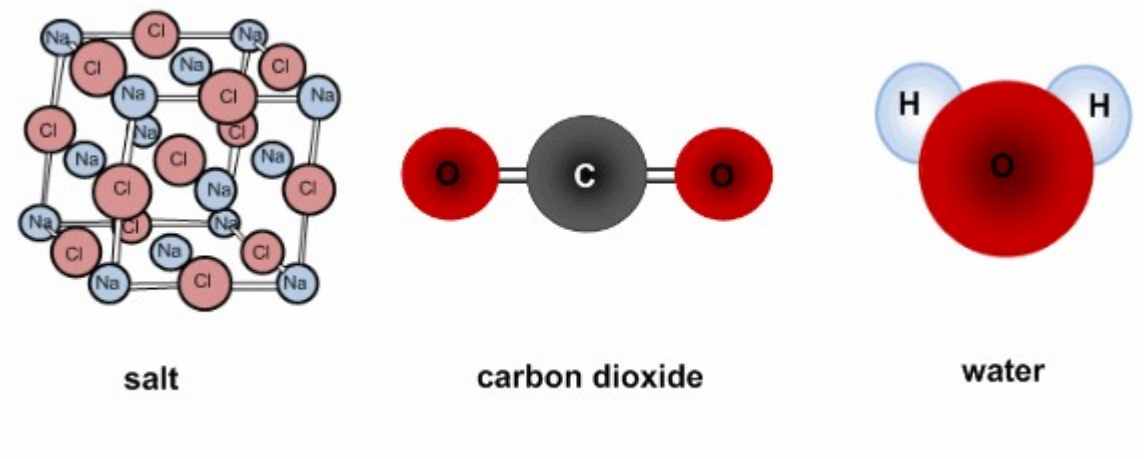
10. The diagrams below illustrate models of various chemical compounds.



The diagrams suggest that compounds must be
○ **A.** made up of oxygen and one other chemical element.
○ **B.** made up of two or more of the same chemical elements only.
○ **C.** made up of two or more different chemical elements.
○ **D.** made up of only one chemical element.
