2.2: Matter

Learning Outcomes

- Define matter.
- Classify pure substances as elements or compounds.
- Classify mixtures as homogeneous or heterogeneous.
- Know the names and symbols of elements indicated in "Things to Memorize" on Canvas.
- Distinguish among metals, nonmetals, and metalloids.

Living things are made of **matter**. In fact, matter is the "stuff" of which all things are made (see figure below. Anything that occupies space and has mass is known as matter. Matter, in turn, consists of chemical substances. **Chemistry** is the study of matter and the changes it undergoes.

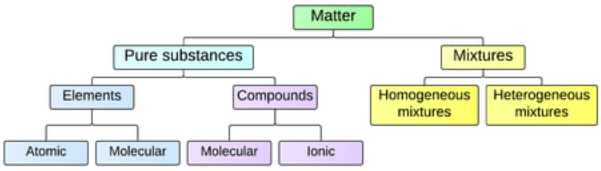

Figure 2.2.1: Matter can be categorized as pure substances or mixtures.

Pure Substances

A pure substance is a material that has a definite chemical composition. It is also homogenous, so the same chemical composition is found uniformly throughout the substance. A pure substance may be an element or a chemical compound.

Elements

An **element** is a pure substance that cannot be broken down into different types of substances. Examples of elements include carbon, oxygen, hydrogen, and iron. Each element is made up of just one type of atom. An atom is the smallest particle of an element that still characterizes the element. As shown in the figure below, at the center of an atom is a nucleus. The nucleus contains positively charged particles called protons and electrically neutral particles called neutrons. Surrounding the nucleus is a much larger electron cloud consisting of negatively charged electrons. An atom is electrically neutral if it has the same number of protons as electrons. Each element has atoms with a characteristic number of protons. For example, all carbon atoms have six protons, and all oxygen atoms have eight protons.

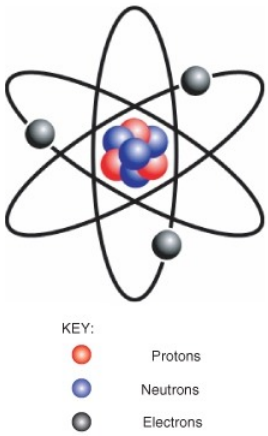

Figure 2.2.2: Model of an atom. The protons and neutrons of this atom make up its nucleus. Electrons surround the nucleus. KEY: Red = protons, Blue = neutrons, Black = electrons.

There are almost 120 known elements (see figure below) and each is represented in the periodic table by a one or two letter symbol. The majority of known elements are classified as metals. Metals are elements that are lustrous, or shiny. They are also good conductors of electricity and heat. Examples of metals include iron, gold, and copper. Fewer than 20 elements are classified as nonmetals. Nonmetals lack the properties of metals. Examples of nonmetals include oxygen, hydrogen, and sulfur. Certain other

elements have properties of both metals and nonmetals. They are known as metalloids. Examples of metalloids include silicon and boron.

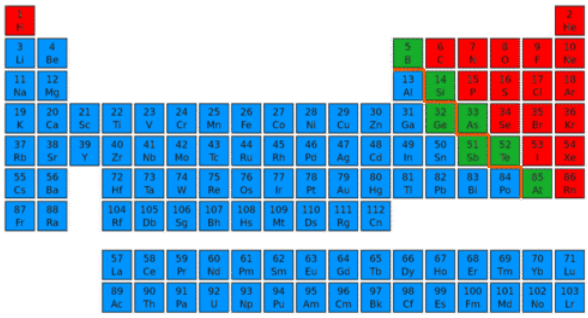

Figure 2.2.3: Periodic table of the elements showing metals (blue), nonmetals (red), and metalloids (green).

The New Periodic Table Song can be heard at https://youtu.be/zUDDiWtFtEM

Tom Lehrer performed the original *The Element Song* in 1967. You can hear it at https://youtu.be/DYW50F42ss8.

Chemical Compounds

A **chemical compound** is a pure substance that forms when atoms of two or more elements react with one another. A compound always has a unique and fixed chemical composition and the atoms of a compound are held together by chemical bonds. There are different types of chemical bonds, and they vary in how strongly they hold together the atoms of a compound. Two types of bonds are covalent and ionic bonds. Covalent bonds form when atoms *share* electrons and occur between two or more nonmetals. Ionic bonds form when electrons are *transferred* from one atom to another and usually form between a metal and a nonmetal.

An example of a chemical compound is water. A water molecule forms when oxygen (O) and hydrogen (H) atoms react and are held together by covalent bonds. Like other compounds, water always has the same chemical composition: a 2:1 ratio of hydrogen atoms to oxygen atoms. This is expressed in the chemical formula for water, $\mathrm{H_2O}$. The ratio of elements in a compound is given by the chemical formula. For example, NaCl has a 1:1 ratio between sodium and chlorine atoms. The absence of a subscripted number within the formula indicates that there is one of that element.

Mixtures

Like a chemical compound, a **mixture** consists of more than one chemical substance. Unlike a compound, a mixture does not have a fixed chemical composition. The substances in a mixture can be combined in any proportions. One characteristic of mixtures is that they can be separated into their components by physical methods. Since each part of the mixture has not reacted with another part of the mixture, the identities of the different substances remain unchanged.

The following examples illustrate these differences between mixtures and compounds. Both examples involve the same two elements: the metal iron (Fe) and the nonmetal sulfur (S).

- When iron fillings and sulfur powder are mixed together in any ratio, they form a mixture (see figure below). No chemical reaction occurs, and both elements retain their individual properties. A magnet can be used to physically separate the two elements by attracting the iron fillings out of the mixture and leaving the sulfur behind.
- When iron and sulfur are mixed together in a certain ratio and *heated*, a chemical reaction occurs. This results in the formation of a unique new compound, called iron (II) sulfide (FeS) (see figure below). A magnet cannot be used to mechanically separate the iron from the iron (II) sulfide because neither iron nor sulfur exist in the compound. Instead, another chemical reaction is required to separate the iron and sulfur.

Figure 2.2.4: Iron and sulfur as a mixture (left) and separated by physical means (right).

Figure 2.2.5: Iron (II) sulfide, FeS, is a chemical compound.

Homogeneous Mixtures

A **homogenous mixture** is a mixture in which the composition is uniform throughout the mixture. A mixture of salt and water is homogenous because the dissolved salt is evenly distributed throughout the entire salt water sample. Often it is easy to confuse a homogeneous mixture with a pure substance because they are both uniform. The difference is that the composition of the substance is always the same, while the composition of a mixture may vary. The amount of salt in the salt water can vary from one sample to another, while water, for example, always has the same composition.

Heterogeneous Mixtures

A **heterogeneous mixture** is a mixture in which the composition is not uniform throughout the mixture. One example of a heterogeneous mixture is vegetable soup. Any given spoonful of soup will contain varying amounts of the different vegetables and other components of the soup. Another example of a heterogeneous mixture is soil which is composed of a variety of substances and is often of different composition depending on the sample taken. One shovel may come up with dirt and grass while the next shovel could contain an earthworm.

See more examples of heterogeneous mixtures at www.buzzle.com/articles/homog...-examples.html

Supplemental Resources

Learn More

- David Bodanis, *$E = mc^2$: A Biography of the World's Most Famous Question*. Walker and Co., 2005
- John Emsley, *Nature's Building Blocks: An A-Z Guide to the Elements*. Oxford University Press, 2003.
- Nevin Katz, *Elements, Compounds, and Mixtures: Middle and High School (Mr. Birdley Teaches Science)*. Incentive Publications, 2007.
- The Science of Macaroni Salad: What's in a Mixture? http://youtu.be/Vt7IN4QPU0k
- Heterogeneous mixtures antoine.frostburg.edu/chem/se...ogeneous.shtml
- Element Flash Cards http://education.jlab.org/elementflashcards/

Contributors and Attributions

-
- Allison Soult, Ph.D. (Department of Chemistry, University of Kentucky)