1.3: Classification of Matter

Learning Objectives

- Categorize different types of matter as a pure substances or mixtures.
- Explain the difference between an element and a compound.
- Explain the difference between a homogeneous mixture and a heterogeneous mixture.

One useful way of organizing our understanding of matter is to think of a hierarchy that extends down from the most general and complex substances to the simplest and most fundamental (Figure 1.3.1). At the top of this hierarchy is two broad categories into which all matter can be classified: pure substances and mixtures. A **pure substance** is a form of matter that has a constant composition (meaning that all samples of this substance have uniform composition) and properties that are constant throughout the sample (meaning that there is only one set of properties such as melting point, color, boiling point, etc. throughout the matter). If we take two or more pure substances and physically mix them together, we refer to this as a **mixture**. A mixture does not have constant composition or properties throughout.

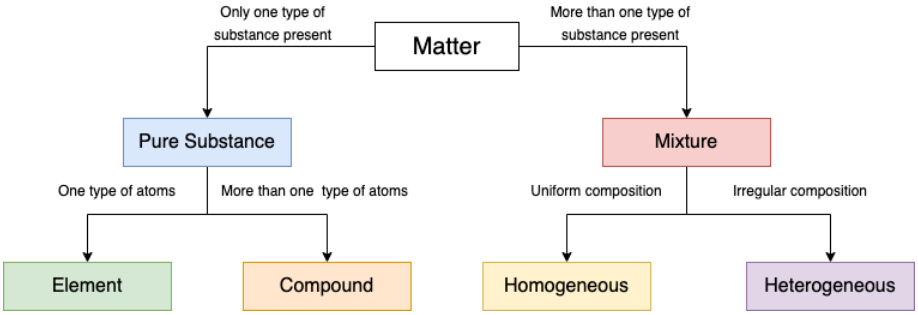

Figure 1.3.1: The Classification of Matter. Matter can be classified in a variety of ways, depending on its properties.

Elements and compounds are both examples of pure substances. A substance that cannot be broken down into chemically simpler components is an **element**. Oxygen, O, and hydrogen, H, are each examples of elements. A pure substance that can be broken down into chemically simpler components (because it made up of more than one element) is a **compound**. For example, the compound water, H_2O, is formed when hydrogen and oxygen chemically combine in a fixed ratio of 2 hydrogen atoms for every 1 oxygen atom.

Compounds may have different chemical and physical properties from the individual elements that they are composed of. Mixtures, on the other hand, are physical blends of two or more components, each of which retains its own identity and properties. Mixtures can always be separated again into the component pure substances, because bonding among the atoms of the constituent substances does not occur. For example sodium is a soft shiny metal and chlorine is a pungent green gas. These two elements chemically combine to form the *compound*, sodium chloride (table salt) which is a white, crystalline solid having *none* of the properties of either sodium or chlorine. If, however, you *mixed* table salt with ground pepper, you would still be able to see the individual grains of each of them and, if you were patient, you could take tweezers and carefully separate them back into pure salt and pure pepper.

Mixtures fall into two categories, based on the uniformity of their composition (Figure 1.3.1). The first, called a **heterogeneous mixture**, is distinguished by the fact that different samples of the mixture may have a different composition. For example, if you open a container of mixed nuts and pull out a series of small samples and examine them, the exact ratio of peanuts-to-almonds in the samples will always be slightly different, no matter how carefully you mix them. Common examples of heterogeneous mixtures include dirt, gravel, and vegetable soup.

In a **homogeneous mixture,** on the other hand, any sample that you examine will have exactly the *same* composition as any other sample. Within chemistry, the most common type of homogeneous mixture is a **solution** which is one substance dissolved completely within another. Think of a solution of pure sugar dissolved in pure water. Any sample of the solution that you examine will have *exactly* the same ratio of sugar-to-water, which means that it is a homogeneous mixture. Even in a homogeneous mixture, the properties of the components are generally recognizable. Thus, sugar-water tastes sweet (like sugar) and is wet (like water). Unlike a compound, which has a fixed, definite ratio, in a mixture the amounts of each component can vary. For example, when you add a little sugar to one cup of tea and a lot of sugar to another, each cup will contain a homogeneous mixture of tea and sugar but they will have a different ratio of sugar-to-tea and a different taste. If you add so much sugar that some does not dissolve and

stays on the bottom, however, the mixture is no longer homogeneous, it is heterogeneous; you could easily separate the two components (Figure 1.3.1).

Example 1.3.1

Identify each substance as a compound, an element, a heterogeneous mixture, or a homogeneous mixture (solution).

a. filtered tea
b. freshly squeezed orange juice
c. a compact disc
d. aluminum oxide, a white powder that contains a 2:3 ratio of aluminum and oxygen atoms
e. selenium

Given: a chemical substance

Asked for: its classification

Strategy:

I. Decide whether a substance is chemically pure. If it is pure, the substance is either an element or a compound. If a substance can be separated into its elements, it is a compound.
II. If a substance is not chemically pure, it is either a heterogeneous mixture or a homogeneous mixture. If its composition is uniform throughout, it is a homogeneous mixture.

Solution

a. I. Tea is a solution of compounds in water, so it is not chemically pure. It is usually separated from tea leaves by filtration.
II. Because the composition of the solution is uniform throughout, it is ***a homogeneous mixture***.
b. I. Orange juice contains particles of solid (pulp) as well as liquid; it is not chemically pure.
II. Because its composition is not uniform throughout, orange juice is ***a heterogeneous mixture***.
c. I. A compact disc is a solid material that contains more than one element, with regions of different compositions visible along its edge. Hence a compact disc is not chemically pure.
II. The regions of different composition indicate that a compact disc is ***a heterogeneous mixture.***
d. I. Aluminum oxide is a single, chemically ***pure compound***.
e. I. Selenium is one of the known ***elements***.

Exercise 1.3.1

Identify each substance as a compound, an element, a heterogeneous mixture, or a homogeneous mixture (solution).

a. white wine
b. mercury
c. ranch-style salad dressing
d. table sugar (sucrose)

Answer a:

homogeneous mixture (solution)

Answer b:

element

Answer c:

heterogeneous mixture

Answer d:

compound

Example 1.3.2

How would a chemist categorize each example of matter?

a. saltwater
b. soil
c. water
d. oxygen

Solution

a. Saltwater acts as if it were a single substance even though it contains two substances—salt and water. Saltwater is a homogeneous mixture, or a solution.
b. Soil is composed of small pieces of a variety of different materials, so it is a heterogeneous mixture.
c. Water is a substance; more specifically, because water is composed of a fixed ratio hydrogen and oxygen atoms, it is a compound.
d. Oxygen, a substance, is an element.

Exercise 1.3.2

How would a chemist categorize each example of matter?

a. coffee
b. hydrogen
c. an egg

Answer a:

Coffee, assuming it is filtered, is a variety of substances dissolved in water, therefore, it is a homogeneous mixture, or a solution.

Answer b:

Hydrogen is a known element.

Answer c:

An egg is composed of many different substances with different compositions between the yolk and white, it is a heterogeneous mixture.

Summary

Matter can be classified into two broad categories: pure substances and mixtures. A pure substance is a form of matter that has a constant composition and properties that are constant throughout the sample. Mixtures are physical combinations of two or more elements and/or compounds. Mixtures can be classified as homogeneous or heterogeneous. Elements and compounds are both examples 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.

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