Pearson

1.1: A Particulate View of the World: Structure Determines Properties

Key Concept Video **Structure Determines Properties**

As I sat in the "omnimover" and listened to the narrator's voice telling me that I was shrinking down to the size of an atom, I grew apprehensive but curious. Just minutes before, while waiting in line, I witnessed what appeared to be full-sized humans entering a microscope and emerging from the other end many times smaller. I was 7 years old and I was about to ride *Adventure Thru Inner Space*, a Disneyland ride (in Tomorrowland) that simulated the process of shrinking down to the size of an atom. The ride began with darkness and shaking, but then the shaking stopped and giant snowflakes appeared. The narrator explained that we were in the process of shrinking to an ever-smaller size (which explains why the snowflakes grew larger and larger). Soon, we entered the wall of the snowflake itself and began to see water molecules all around us. These also grew larger as we continued our journey into inner space and eventually ended up within the atom itself. Although this Disneyland ride bordered on being corny and although it has since been shut down, it became my favorite ride as a young child.

That ride sparked my interest in the world of atoms and molecules, an interest that has continued and grown to this day. I am a chemist because I am obsessed with the connection between the "stuff" around us and the particles that compose that stuff, which is the core of chemistry and the main idea of this book. We can express this core idea more precisely in two brief statements:

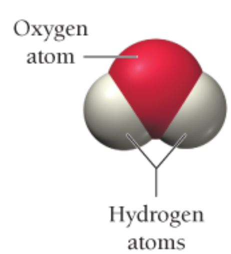
1. Matter is particulate—it is composed of particles.
2. The structure of those particles determines the properties of matter.

Matter is anything that occupies space and has mass. Most things you can think of—such as this book, your desk, and even your body—are composed of matter. The particulate nature of matter—first conceived in ancient Greece but widely accepted only about 200 years ago—is the foundation of chemistry and the premise of this book.

> In chemistry, atoms are often portrayed as colored spheres, with each color representing a different kind of atom. For example, a black sphere represents a carbon atom, a red sphere represents an oxygen atom, and a white sphere represents a hydrogen atom. For a complete color code of atoms, see Appendix IIA.

As an example of this premise, consider water, the familiar substance we all know and depend on for life. The particles that compose water are *water molecules*, which we can represent like this:

Water molecule



A water molecule is composed of three *atoms*: one oxygen atom and two hydrogen atoms. **Atoms** are the basic particles that compose ordinary matter, and about 91 different types of atoms naturally exist. Atoms often bind together in specific geometrical arrangements to form **molecules**, as we see in water.

> Atoms themselves, as we discuss later in this chapter, are composed of even smaller particles.

The first thing you should know about water molecules—and all molecules—is that they are extremely small, much too small to see with even the strongest optical microscope. The period at the end of this sentence has a diameter of about one-fifth of a millimeter (less than one-hundredth of an inch); yet a spherical drop of water with the same diameter as this period contains over 100 million billion water molecules.

The second thing you should know about water molecules is that their structure determines the properties of water. The water molecule is *bent*: The two hydrogen atoms and the oxygen atom are not in a straight line. If the atoms were in a straight line, water itself would be different. For example, suppose that the water molecule were linear instead of bent:

Hypothetical linear water molecule

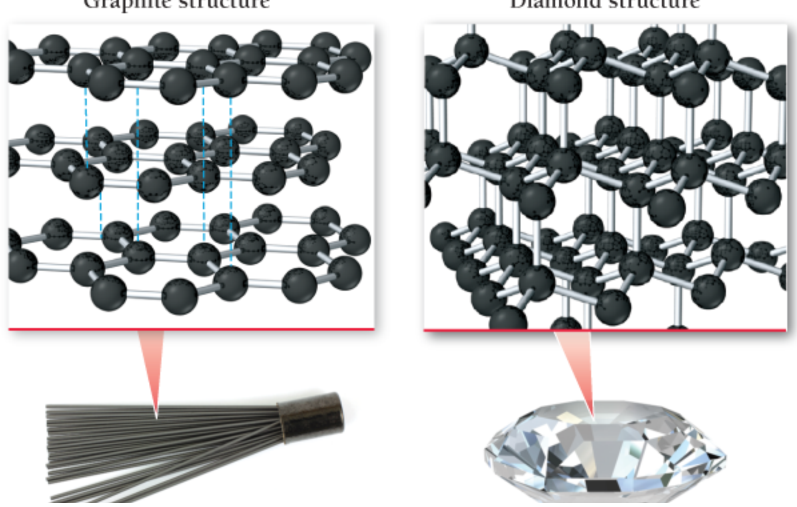
If water had this hypothetical structure, it would be a different substance. First of all, linear water would have a lower boiling point than normal water (and may even be a gas at room temperature). Just this change in shape would cause the attractive forces between water molecules to weaken so that the molecules would have less of a tendency to clump together as a liquid and more of a tendency to evaporate into a gas. In its liquid form, linear water would be quite different than the water we know. It would feel more like gasoline or paint thinner than water. Substances that normally dissolve easily in water—such as sugar or salt—would probably not dissolve in linear water.

The key point here is that the properties of the substances around us radically depend on the structure of the particles that compose them—a small change in structure, such as a different shape, results in a significant change in properties. If we want to understand the substances around us, we must understand the particles that compose them—and that is the central goal of chemistry. A good, simple definition of **chemistry** is:

> **Chemistry—the science that seeks to understand the properties of matter by studying the structure of the particles that compose it.**

Throughout this book, we explore the connection between the properties of matter and the particles that compose it. We seek to understand how differences on the particulate level affect the properties on the macroscopic level. Before we move on, let's examine one more example that demonstrates this principle. Consider the structures of graphite and diamond.

Graphite structure | Diamond structure



Graphite Diamond

Graphite is the slippery black substance (often called pencil lead) that you have probably used in a mechanical pencil. Diamond is the brilliant gemstone found in jewelry. Graphite and diamond are both composed of exactly the same atoms—carbon atoms. The striking differences between the substances are a result of how those atoms are arranged. In graphite, the atoms are arranged in sheets. The atoms within each sheet are tightly bound to each other, but the sheets are *not* tightly bound to other sheets. Therefore, the sheets can slide past each other, which is why the graphite in a pencil leaves a trail as you write. In diamond, by contrast, the carbon atoms are all bound together in a three-dimensional structure where layers are strongly bound to other layers, resulting in the strong, nearly unbreakable substance. Such is the particulate world—small differences in the arrangements of the particles that compose matter can result in large differences in the properties of that matter.