4.1 Defining the Atom

Connecting to Your World

It often helps to take a closer look. For example, you might walk up to a sign or a poster in order to make out the details. Or you might bring a set of binoculars to a sports stadium so that you can zoom in on the action.

The lab technician shown here is using a magnifying lens to examine a bacterial culture in a petri dish. Scientists use many different devices that enhance their ability to see. However, scientists can't always see the details of what they study. In such cases, scientists try to obtain experimental data that helps fill in the picture.

Guide for Reading

Key Concepts

- How did Democritus describe atoms?
- How did John Dalton further Democritus's ideas on atoms?
- What instruments are used to observe individual atoms?

Vocabulary

atom

Dalton's atomic theory

Reading Strategy

Summarizing As you read about early atomic models, summarize the main ideas in the text that follow each red and blue heading.

Early Models of the Atom

Have you ever been asked to believe in something you couldn't see? Using your unaided eyes, you cannot see the tiny fundamental particles that make up matter. Yet all matter is composed of such particles, which are called atoms. An **atom** is the smallest particle of an element that retains its identity in a chemical reaction.

The concept of the atom intrigued a number of early scholars. Although these philosophers and scientists could not observe individual atoms, they still were able to propose ideas on the structure of atoms.

Democritus's Atomic Philosophy The Greek philosopher Democritus (460 B.C.–370 B.C.) was among the first to suggest the existence of atoms. **Democritus believed that atoms were indivisible and indestructible.** Although Democritus's ideas agreed with later scientific theory, they did not explain chemical behavior. They also lacked experimental support because Democritus's approach was not based on the scientific method.

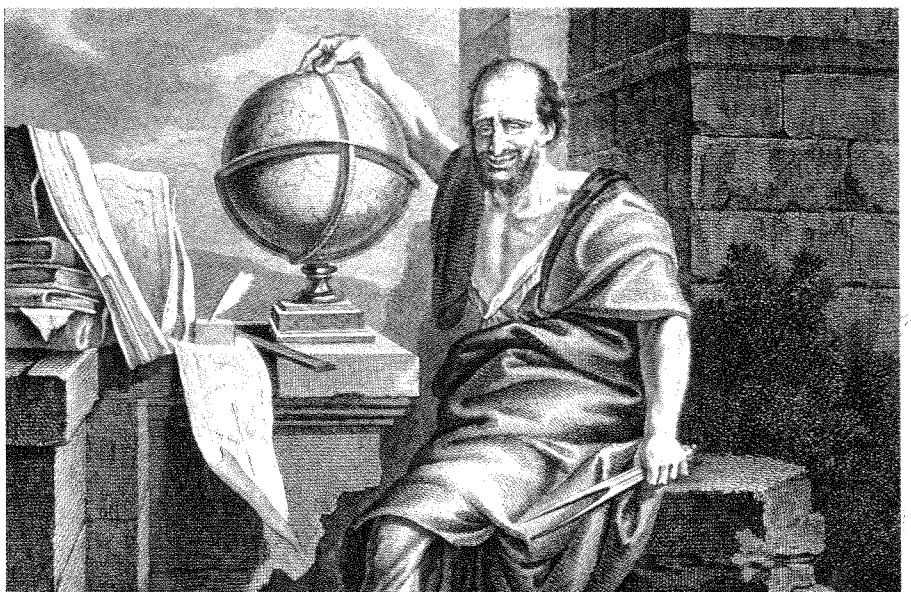

Figure 4.1 Democritus believed that matter consisted of tiny, indivisible, unchangeable particles called atoms. His ideas were later challenged by the Greek philosophers Plato and Aristotle.

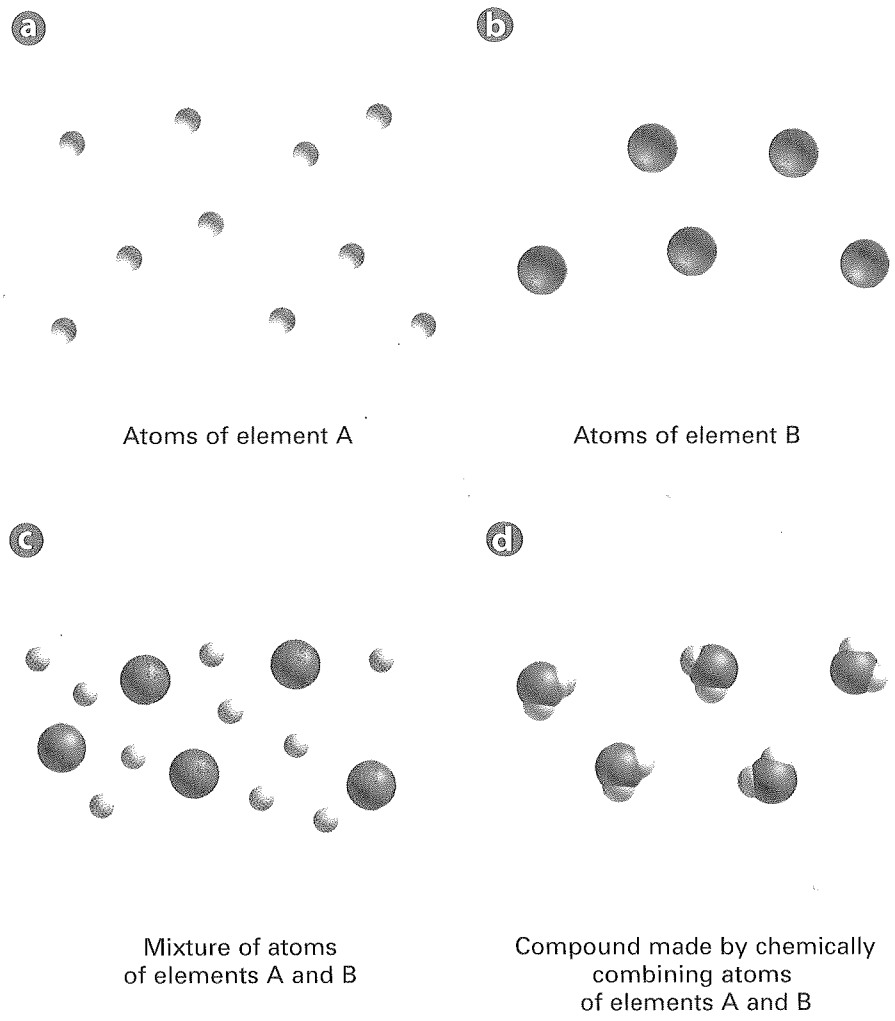

Figure 4.2 According to Dalton's atomic theory, an element is composed of only one kind of atom, and a compound is composed of particles that are chemical combinations of different kinds of atoms. ⓐ Atoms of element A are identical. ⓑ Atoms of element B are identical, but differ from those of element A. ⓒ Atoms of elements A and B can physically mix together. ⓓ Atoms of elements A and B can chemically combine to form a compound. **Interpreting Diagrams** ***How does a mixture of atoms of different elements differ from a compound?***

Word *Origins*

Atom comes from the Greek word *atomos,* meaning "indivisible." **If the suffix *-ize* means "to become like," what do you think the word *atomize* means?**

Dalton's Atomic Theory The real nature of atoms and the connection between observable changes and events at the atomic level were not established for more than 2000 years after Democritus. The modern process of discovery regarding atoms began with John Dalton (1766–1844), an English chemist and schoolteacher. **By using experimental methods, Dalton transformed Democritus's ideas on atoms into a scientific theory.** Dalton studied the ratios in which elements combine in chemical reactions. Based on the results of his experiments, Dalton formulated hypotheses and theories to explain his observations. The result was **Dalton's atomic theory,** which includes the ideas illustrated in Figure 4.2 and listed below.

1. All elements are composed of tiny indivisible particles called atoms.
2. Atoms of the same element are identical. The atoms of any one element are different from those of any other element.
3. Atoms of different elements can physically mix together or can chemically combine in simple whole-number ratios to form compounds.
4. Chemical reactions occur when atoms are separated, joined, or rearranged. Atoms of one element, however, are never changed into atoms of another element as a result of a chemical reaction.

Checkpoint ***What happens to atoms in a chemical reaction according to Dalton's atomic theory?***

Sizing up the Atom

A coin the size of a penny and composed of pure copper (Cu) illustrates Dalton's concept of the atom. Imagine grinding the copper coin into a fine dust. Each speck in the small pile of shiny red dust would still have the properties of copper. If by some means you could continue to make the copper dust particles smaller, you would eventually come upon a particle of copper that could no longer be divided and still have the chemical properties of copper. This final particle is an atom.

Copper atoms are very small. A pure copper coin the size of a penny contains about 2.4×10^{22} atoms. By comparison, Earth's population is only about 6×10^{9} people. There are about 4×10^{12} times as many atoms in the coin as there are people on Earth. If you could line up 100,000,000 copper atoms side by side, they would produce a line only 1 cm long!

The radii of most atoms fall within the range of 5×10^{-11} m to 2×10^{-10} m. Does seeing individual atoms seem impossible? **Despite their small size, individual atoms are observable with instruments such as scanning tunneling microscopes.** Figure 4.3 shows an image of iron atoms generated by a scanning tunneling microscope. Individual atoms can even be moved around and arranged in patterns. The ability to move individual atoms holds future promise for the creation of atomic-sized electronic devices, such as circuits and computer chips. This atomic-scale, or "nanoscale," technology could become essential to future applications in medicine, communications, solar energy, and space exploration.

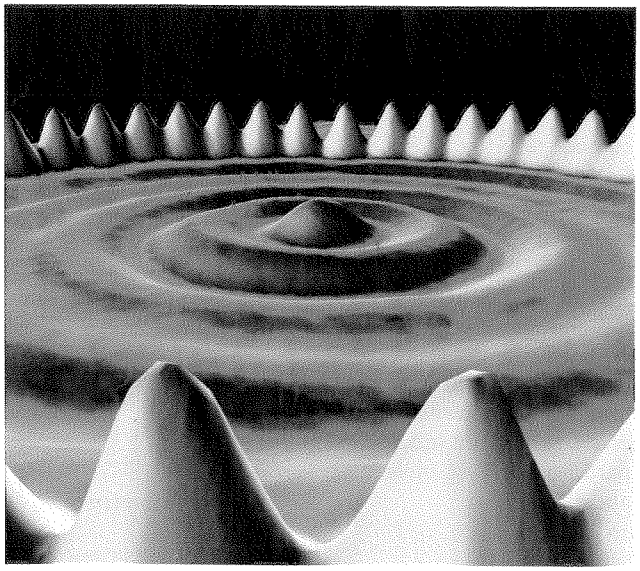

Figure 4.3 Scientists used a scanning tunneling microscope to generate this image of iron atoms, shown in blue. The radius of this circle of atoms is just 7.13×10^{-9} m.

4.1 Section Assessment

1. **Key Concept** How did Democritus characterize atoms?
2. **Key Concept** How did Dalton advance the atomic philosophy proposed by Democritus?
3. **Key Concept** What instrument can be used to observe individual atoms?
4. In your own words, state the main ideas of Dalton's atomic theory.
5. According to Dalton's theory, is it possible to convert atoms of one element into atoms of another? Explain.
6. Describe the range of the radii of most atoms in nanometers (nm).
7. A sample of copper with a mass of 63.5 g contains 6.02×10^{23} atoms. Calculate the mass of a single copper atom.

Connecting Concepts

Scientific Methods Reread the description of scientific methods in Section 1.3. Explain why the ideas on atoms proposed by Dalton constitute a theory, while the ideas proposed by Democritus do not.

Interactive Textbook

Assessment 4.1 Test yourself on the concepts in Section 4.1.

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