

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.

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.

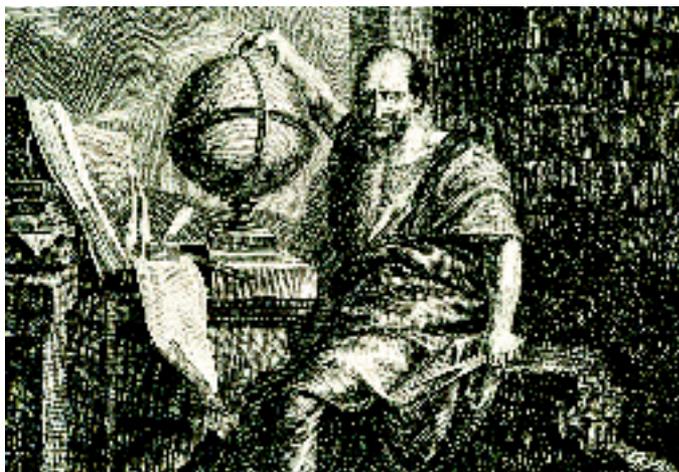


Figure 4.1 Democritus believed that matter consisted of tiny, indivisible, unchangeable particles called atoms. His ideas were later challenged by the Greek philosophers Plato and Aristotle.

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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.

4.1

1 FOCUS

Objectives

- 4.1.1 Describe** Democritus's ideas about atoms.
- 4.1.2 Explain** Dalton's atomic theory
- 4.1.3 Understand** that special instruments are necessary to observe individual atoms.

Guide for Reading

Build Vocabulary

L2

List the Parts You Know Discuss what a scientific theory is. (*an explanation of the way the world works, based on observation*)

Reading Strategy

L2

Visualize Ask students to think about these questions as they read this chapter.

- **What could you do if someone asked you to describe something that is too small to see?**
- **How would you find out what it looked like?**

2 INSTRUCT

Connecting to Your World

Ask students to think of objects that require experimental data in order to "picture" them, either because they are small or inaccessible. (*Acceptable answers include: objects in deep space or deep underground*)

Early Models of the Atom

Discuss

L2

Early philosophers and scientists developed models of the atom to help explain the nature of matter. Tell students that in the same way that they might use a globe to learn about Earth, they can use an atomic model to learn about atoms. Ask, **Why do people use models?** (*to study things too large, too small, or too complex to easily see or understand*) **What models do you use or have you used?** (*Acceptable answers include subway maps or weather maps.*) Students will learn more about atomic models in Sections 4.2 and 5.1.



Section Resources

Print

- **Guided Reading and Study Workbook**, Section 4.1
- **Core Teaching Resources**, Section 4.1 Review
- **Transparencies**, T43–T44

Technology

- **Interactive Textbook with ChemASAP**, Assessment 4.1

Section 4.1 (continued)

Discuss

L2

Explain that John Dalton's work, published in 1808, became the basis for modern atomic theory. This model represented the atom as a simple sphere with no internal structure. Point out how experimental data have been used to test and refine atomic theory over time.

Use Visuals

L1

Figure 4.2 Point out that the particles in Figure 4.2d represent a compound such as water. Ask, **How many atoms of A and of B form one particle in Figure 4.2d? (2 A and 1 B)** Do you think that a mixture, shown in Figure 4.2c, always leads to compounds, shown in Figure 4.2d? Why? (No; some atoms may not readily combine.)

Word Origins

L2

Atomize means to make something as small as an atom, or at least very small. Ask students to think of other words containing the suffix *-ize* and what they mean (e.g., customize, randomize, itemize).

Sizing Up the Atom

Use Visuals

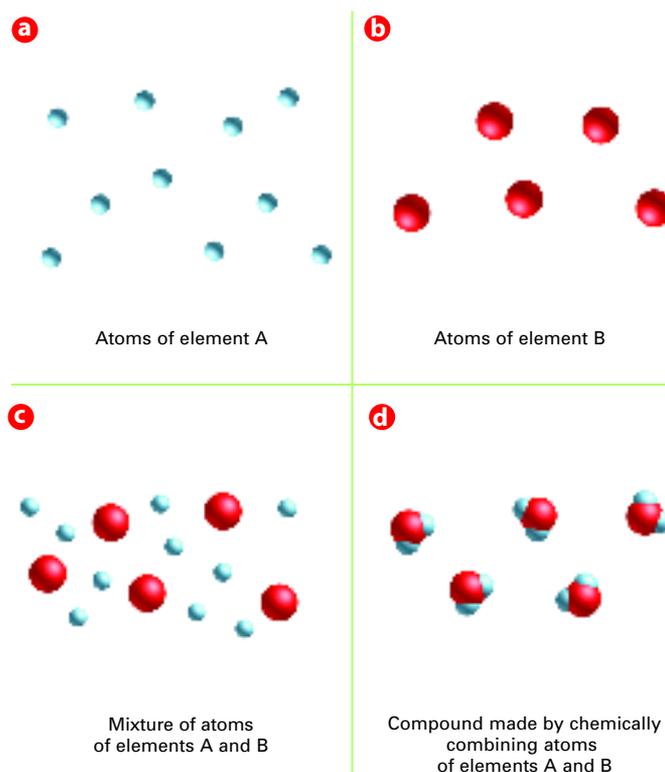
L2

Figure 4.3 Point out that the image in Figure 4.3 is greatly magnified. Ask, **What is the radius of the circle of atoms in nanometers? (7.13 nm)** In picometers? (7130 pm)

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.

a Atoms of element A are identical. **b** Atoms of element B are identical, but differ from those of element A. **c** Atoms of elements A and B can physically mix together. **d** 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?

Facts and Figures

Scanning Tunneling Microscope

A scanning tunneling microscope (STM) holds a one-atom-sized tip over a sample that conducts electricity. Electric current flows between the tip and the sample.

The current is stronger when the tip and the sample are close and weaker when they are farther apart. This change in voltage is interpreted to show surface topography.

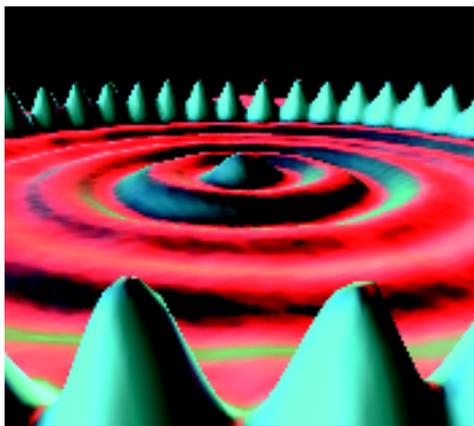
Sizing up the Atom

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} 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^{-13} 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

-  **Key Concept** How did Democritus characterize atoms?
-  **Key Concept** How did Dalton advance the atomic philosophy proposed by Democritus?
-  **Key Concept** What instrument can be used to observe individual atoms?
- In your own words, state the main ideas of Dalton's atomic theory.
- According to Dalton's theory, is it possible to convert atoms of one element into atoms of another? Explain.
- Describe the range of the radii of most atoms in nanometers (nm).
- 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 1.4. Explain why the ideas on atoms proposed by Dalton constitute a theory, while the ideas proposed by Democritus do not.



Assessment 4.1 Test yourself on the concepts in Section 4.1.

with ChemASAP

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ASSESS

Evaluate Understanding L2

Have students evaluate and criticize the following statements according to Dalton's theory:

- **"All atoms are identical."** (Dalton said: "All atoms of a given element are identical.")
- **"Chemical reactions occur when atoms of one element change into atoms of another element."** (Chemical reactions occur when atoms are separated, joined, or rearranged. The elemental identity of atoms does not change during chemical reactions.)

Reteach L1

Review Dalton's model of the atom. Discuss how STM could be used to support or contest Dalton's theory. (No matter how small the sample, you can see that there are many similar atoms in each sample. You could also see where atoms are and whether they change after a reaction.)

Connecting Concepts

Democritus's ideas were not based on experimental results and did not explain chemical behavior. Dalton's ideas were empirically based and did explain chemical behavior; his experiments showed that the ratios in which elements combined were whole numbers.



If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 4.1.

with ChemASAP

Section 4.1 Assessment

- as indivisible and indestructible.
- by using experimental methods
- a scanning tunneling microscope
- Answers should include the ideas that all matter is composed of atoms; atoms of different elements differ; and chemical change involves a rearrangement of atoms.
- Atoms of one element are never changed into atoms of another element as a result of a chemical reaction.
- 5×10^{-2} nm to 2×10^{-1} nm
- 1.05×10^{-22} g

Answers to...

Figure 4.2 In a mixture of atoms of different elements, each element in the mixture retains its chemical properties. In a compound, different elements have been combined to form a new substance with chemical properties different from its component elements.



Checkpoint Atoms are separated, joined, or rearranged.