Name _____ Class _____ Date _____

CHAPTER 4 Introduction to Atoms

SECTION 1

# Development of the Atomic Theory

**BEFORE YOU READ**

**After you read this section, you should be able to answer these questions:**

- What is the atomic theory?
- How has the atomic theory changed over time?

## How Does New Information Change Scientific Ideas?

Have you ever watched a mystery movie and thought you knew who the criminal was? You may have changed your mind once you saw a new fact or clue. This is what happens in science. Sometimes an idea or a model is changed when new information is collected. One example of this is the atomic model. Our ideas about atoms have changed over time as we gather new information.

**STUDY TIP**

**Connect Concepts** In your notebook, create a Concept Map about the scientists who studied atoms and what they learned.

## What Is an Atom?

Imagine cutting something in half, then cutting again and again. Could you keep cutting forever? Around 440 BCE, a Greek philosopher named Democritus studied this question. He thought that you would eventually reach a piece of matter that could not be cut. He called this particle an atom.

It was a long time before there was scientific evidence that Democritus was on the right track. We now know that all matter is made of tiny particles called atoms. An **atom** is the smallest particle into which an element can be divided and still keep its properties. ☑

**READING CHECK**

**1. Identify** What is an atom?

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The figure shows images of aluminum atoms taken with a scanning tunneling electron microscope. Early scientists had ideas about atoms and models of atoms even though they did not have pictures of them.

Aluminum cans are made of atoms. Aluminum atoms can be seen in the image from a scanning tunneling electron microscope (STM). Notice the regular, repeating pattern of the aluminum atoms.

**TAKE A LOOK**

**2. Describe** How are the atoms of aluminum arranged?

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## What Was the First Scientific Theory of Atoms?

The first scientific theory about atoms was published by John Dalton in 1803. Unlike Democritus, Dalton based his ideas on experiments. His theory helped explain observations that he and other scientists had made about elements and compounds. Dalton's theory stated that:

- All substances are made of atoms. Atoms are small particles that cannot be created, destroyed, or divided.
- All atoms of one element are exactly alike, and atoms of different elements are different.
- Atoms can join with other atoms to make new substances.

Many scientists agreed that Dalton's theory explained much of what they saw. However, scientists later found new information that did not fit Dalton's theory. The atomic theory was changed to more correctly describe the atom. ☑

**READING CHECK**

**3. Discuss** When would scientists need to change a theory?

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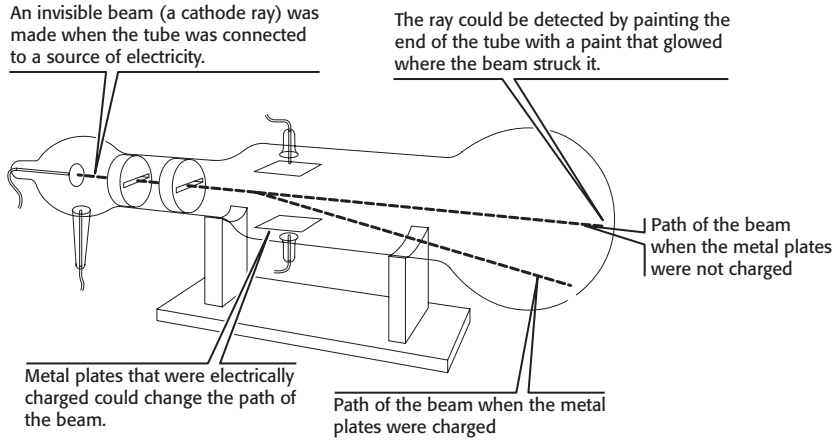
## How Were Electrons Discovered?

In 1897, J. J. Thomson, a British scientist, discovered that atoms are not the smallest particles. There are even smaller particles inside the atom. Thomson made this discovery when he was experimenting with invisible beams called *cathode rays*. Cathode rays were made by connecting a special glass tube to a source of electricity.

To find out more about cathode rays, Thomson placed two metal plates inside the tube. One plate had a positive electrical charge and the other had a negative charge. Thomson discovered that cathode rays are attracted to the plate with the positive charge.

**Thomson's Cathode-Ray Tube Experiment**




**TAKE A LOOK**

**4. Identify** What is the electrical charge on the plate that causes the beam to bend toward that plate?

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### THOMSON'S PLUM PUDDING MODEL

Thomson concluded that cathode rays must be made of tiny particles that come from atoms. Since the particles are attracted to a positively charged metal plate, the particles must have a negative charge. Remember that opposite charges attract each other. These negatively charged particles are called **electrons**. ☑

Thomson's experiment showed that atoms contain electrons, but it did not show where electrons are located within an atom. Thomson suggested that electrons might be scattered throughout the atom. This new model of the atom was called the plum pudding model. It was named after a popular dessert at the time. Today, we would probably call this a "chocolate chip ice cream" model of the atom.

**READING CHECK**

**5. Identify** What type of electrical charge does an electron have?

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## How Did Rutherford Study the Atom?

In 1909, one of Thomson's students wanted to test the theory that electrons are scattered throughout the atom. Ernest Rutherford decided to shoot a beam of tiny, positively charged particles at a thin sheet of gold foil. ☑

Rutherford guessed that atoms are soft blobs of matter with electrons and positively charged particles scattered throughout. He thought that most of the particles would pass right through the gold atoms. Particles that hit other particles would stop or bounce to the side.

When Rutherford performed the experiment, he found that most of the positively charged particles did pass through the gold foil. Some were deflected sideways, just as he expected. What surprised him was that some particles bounced straight back.

**READING CHECK**

**6. Identify** What did Rutherford shoot at the gold foil in his experiment?

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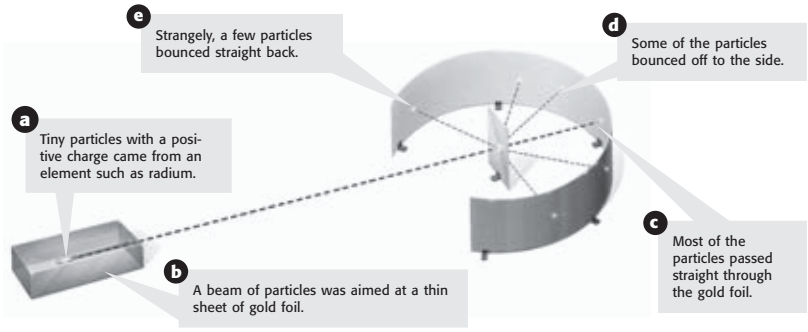
**Rutherford's Gold-Foil Experiment**




**TAKE A LOOK**

**7. Compare** What happened to most of the particles that were shot at the gold foil?

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## What Was Rutherford's Atomic Model?

The plum pudding model did not explain what Rutherford saw. He reasoned that there was only one way that the positively charged particles could bounce straight back. That was if they hit a very dense part of the atom that had a positive charge. Remember that identical charges repel. He concluded that most of the matter in the atom must be in a very small part of the atom.

Based on the results of his experiment, Rutherford proposed a new model of the atom, called the *nuclear model*. In his model, the center of the atom is a tiny, dense, positively charged area called the **nucleus**. The electrons move outside the nucleus in mostly empty space. ☑

**READING CHECK**

**8. Describe** What is the nuclear model of the atom?

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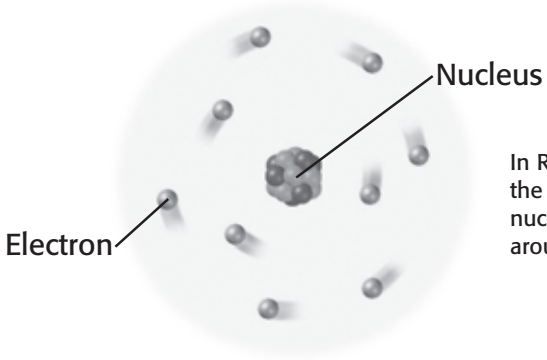


In Rutherford's model, the atom contains a nucleus. Electrons move around the nucleus.

## Math Focus

**9. Make Comparisons** If an atom had a nucleus 1 ft in diameter, what would be the diameter of the atom, in miles? Show your work. Round to the nearest mile. (1 mi = 5,280 ft)

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Rutherford concluded that the nucleus must be very small but very dense in order to deflect the fast-moving particles. He used his observations to calculate the diameter of an atom. It was about 100,000 times greater than the diameter of its nucleus. The atom is mostly empty space.

## What Did Bohr Discover about the Atom?

In 1913, Niels Bohr, a Danish scientist, studied the way that atoms react to light. He made a slight change to Rutherford's model, based on his observations.

Bohr proposed that electrons move around the nucleus in definite paths, or *orbits*, called energy levels. In Bohr's model, electrons could not exist between these levels. Think of the levels as rungs on a ladder. You can stand on the rungs of a ladder, but not between the rungs. However, the electrons could jump from one level to another as they gained or lost energy. Once again, the atomic theory was changed to account for new data. ☑

**READING CHECK**

**10. Describe** According to Bohr's theory, how do electrons move around the nucleus?

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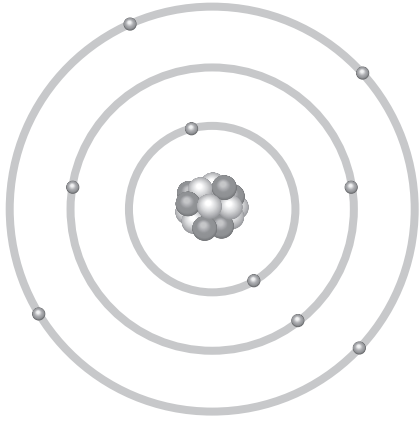
### Bohr Model of the Atom



In the Bohr model, electrons move around the nucleus like planets around the sun.

**TAKE A LOOK**

**11. Identify** Label the nucleus and the electrons in the figure.

## What Is the Modern Atomic Theory?

Atomic theory has changed over the past 100 years. Scientists such as Erwin Schrödinger from Austria and Werner Heisenberg from Germany have done important work. They have made observations that show that the Bohr model is not quite right.

Scientists still think that electrons are moving constantly around the nucleus. However, they now know that electrons do not orbit the nucleus like planets orbit the sun. In fact, no one can predict the exact path an electron will follow as it moves around the nucleus. However, scientists can predict where electrons are likely to be found.

In the modern atomic model, the locations of electrons are described with electron clouds. **Electron clouds** are regions where electrons are most likely to be found. The figure below shows this model. ☑

**READING CHECK**

**12. Define** What are electron clouds?

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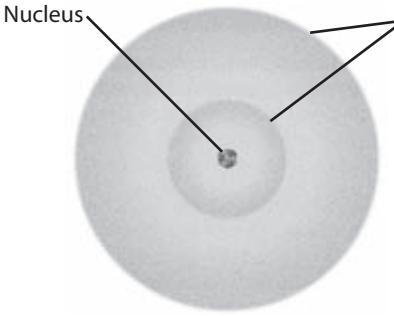


In the current model of the atom, electrons move around the nucleus in electron clouds. No one can say exactly where a particular electron is at any particular time.

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# Section 1 Review

## SECTION VOCABULARY

| | |
|---|---|
| **atom** the smallest unit of an element that maintains the properties of that element | **electron cloud** a region around the nucleus of an atom where electrons are likely to be found |
| **electron** a subatomic particle that has a negative charge | **nucleus** in physical science, an atom's central region, which is made up of protons and neutrons |

1. **Describe** How does the diameter of an atom compare with the diameter of the nucleus?

2. **Recall** Finish the table below to summarize some of the advances in the development of atomic theory and those responsible for them.

| Scientist | Idea that was added to the atomic theory |
|---|---|
| | Each element is made of a different type of atom. |
| Thomson | |
| Rutherford | |
| | Electrons are found in specific energy levels. |
| Modern scientists | |

3. **Apply** How did the discovery of electrons show that there are also positively charged parts of the atom?

4. **Evaluate** What would cause scientists to change or replace the modern atomic theory?

5. **Explain** Describe Thomson's plum pudding model of the atom.

### SECTION 2 COMPOUNDS

1. a pure substance composed of two or more elements that are joined by chemical bonds
2. 1:4
3. Room temperature is about 25°C. This value falls between the melting point and the boiling point of each of the three compounds.
4. sodium
5. They are different.
6. heat
7. proteins and carbohydrates

#### Review

1. The particles of a compound contain atoms of more than one element. The particles of an element are the atoms of that element.
2. physical, chemical, elements, heat or electricity
3. There was a chemical reaction with something in the air. It formed a new compound that had properties different from those of copper.
4. heat and electricity
5. 1:2

### SECTION 3 MIXTURES

1. a physical change
2. The components in the mixtures are not changed.
3. the flame or the burner
4. A pure substance has the same particles throughout, so it cannot separate into layers.
5. the water
6. The ratio of components in a mixture is not fixed, but a compound always has the same elements in the same ratio.
7. the solvent
8. water
9. It is not a solution, because the metals are not spread evenly throughout the coin.
10. Oxygen, carbon dioxide, alcohol, salt, and zinc should be circled.
11. amount of solute and amount of solution
12. You add more than the solubility of sugar in water.
13. 160 g/100 mL of water
14. $concentration = \frac{grams\ of\ solute}{milliliters\ of\ solvent}$

    $concentration = \frac{55\ g}{500}\ mL = 0.11\ g/mL$
15. low temperatures
16. mixing by stirring, heating the solution, crushing the solid
17. a mixture in which the particles of a material are large enough to settle out
18. by passing it through a filter
19. a mixture in which the particles are spread throughout but are not large enough to settle out

#### Review

1. The solvent is ethanol; the solute is sucrose.
2. Middle box: solution

    Bottom boxes, from left to right: solvent, solute
3. $concentration = \frac{grams\ of\ solute}{milliliters\ of\ solvent}$

    $concentration = \frac{25\ g}{400}\ mL = 0.0625\ g/mL$
4. The solubility of sugar is lower in cold water than in hot water, so some of the sugar came out of solution.

## Chapter 4 Introduction to Atoms

### SECTION 1 DEVELOPMENT OF THE ATOMIC THEORY

1. An atom is the smallest particle of an element that keeps its properties.
2. in a regular or repeating pattern
3. when new information is found that does not fit the original theory
4. positive
5. negative
6. a beam of small, positively charged particles
7. Most particles followed a straight path.
8. In the center of the atom is the nucleus. Electrons move in mostly empty space outside the nucleus.
9. about 19 mi
10. Electrons move around the nucleus in definite areas called energy levels.
11. The nucleus is the center circle. The nine smaller circles are electrons.
12. Electron clouds are regions where electrons are likely to be found.

### Review

1. The diameter of the atom is about 100,000 times larger than the diameter of the nucleus.
2.

| Scientist | Idea that was added to the atomic theory |
|---|---|
| Dalton | Each element is made of a different type of atom. |
| Thomson | Atoms have negative particles called electrons. |
| Rutherford | The positive part of the atom, the nucleus, is small and dense. |
| Bohr | Electrons are found in specific energy levels. |
| Modern scientists | You cannot predict exactly where an electron is or what path it will take. |

3. Atoms are electrically neutral, so if they contain negative particles, they must also contain positive particles to balance the charge.
4. discovery of new facts about atoms that are not consistent with the modern atomic theory
5. Thomson's model said that the electrons are scattered throughout the atom.

## SECTION 2 THE ATOM

1. protons, neutrons, electrons
2. Electrons are negatively charged particles found in electron clouds outside the nucleus. Protons are positively charged particles in the nucleus of an atom. Neutrons are particles in the nucleus of an atom that have no charge.
3. atomic mass unit, or amu
4. electron clouds outside the nucleus
5.

| Particle | Charge | Mass (amu) |
|---|---|---|
| Proton | 1+ | 1 |
| Neutron | 0 | 1 |
| Electron | 1− | 1/1,840 |

6. They have different numbers of protons.
7. to keep the protons from moving apart
8. because protons alone repel each other
9. the number of protons in the nucleus of an atom
10.

| Element | Hydrogen | Helium |
|---|---|---|
| Number of protons | 1 | 2 |
| Number of neutrons | 0 | 2 |
| Number of electrons | 1 | 2 |
| Atomic number | 1 | 2 |

11. atoms that have the same number of protons but a different number of neutrons
12. The number of neutrons does not affect the chemical properties of oxygen.
13. 5 neutrons in boron-10 and 6 neutrons in boron-11
14.

| Isotope | Mass number | Atomic number |
|---|---|---|
| Hydrogen-2 | 2 | 1 |
| Helium-4 | 4 | 2 |
| Carbon-13 | 13 | 6 |
| Oxygen-16 | 16 | 8 |

15. No, the mass number is the atomic number plus the number of neutrons, so it can never be smaller than the atomic number.
16. $(10 \times 0.20 = 2.0) + (11 \times 0.80 = 8.8) = 10.8$ amu
17. The atom changes into an atom of a different element because there is one more proton in the nucleus.
18. **Forces in the Atom**

| Description | Force |
|---|---|
| Force that affects changes of particles in the nucleus | weak force |
| Attractive interaction between objects with mass | gravitational force |
| Attractive force between particles in the nucleus | strong force |
| Attractive or repulsive force between objects with opposite charges | electromagnetic force |

### Review

1. All atoms of an element have the same number of protons, so they have the same atomic number. Isotopes have different numbers of neutrons, so they have different mass numbers.
2. neutron, charge is 0, proton, charge is +1, electron, charge is −1
3. Without neutrons, the repulsion of the protons would cause the nucleus to break apart.
4. Each atom of carbon has 6 protons in its nucleus, and each atom of nitrogen has 7 protons. So, the number of neutrons in carbon-14 is $14 - 6 = 8$ neutrons. The number of neutrons in nitrogen-14 is $14 - 7 = 7$ neutrons.
5. $(69 \times 0.6) + (71 \times 0.4) = 41.4 + 28.4 = 69.8$ amu