Understanding the Atom

Discovering Parts of an Atom

Before You Read

What do you think? Read the three statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	1. The earliest model of an atom contained only protons and electrons.	
	2. Air fills most of an atom.	
	3. In the present-day model of the atom, the nucleus of the atom is at the center of an electron cloud.	

Key Concepts

- What is an atom?
- How would you describe the size of an atom?
- How has the atomic model changed over time?

Read to Learn

Early Ideas About Matter

Look at your hands. What are they made of? You might answer that your hands are made of things such as skin, bone, muscle, and blood. Recall that each of these is made of even smaller structures called cells. Are cells made of even smaller parts? Imagine dividing something into smaller and smaller parts. What would the smallest part be?

Greek philosophers discussed and debated questions such as these more than 2,000 years ago. Most of them thought that all matter is made of only four elements—fire, water, air, and earth. However, they could not test their ideas. The scientific tools and methods for testing, such as experimentation, did not yet exist. The ideas proposed by the most influential philosophers usually were accepted over the ideas of less-influential philosophers. The popular idea of matter was challenged by Democritus (460–370 B.C.).

Democritus

The philosopher Democritus believed that matter is made of small, solid objects that cannot be divided, created, or destroyed. He called these objects *atomos*, from which the English word *atom* is derived.

Study Coach

Create a Quiz Write five questions about discovering parts of the atom to create a quiz. Exchange quizzes with a partner. After taking the quizzes, discuss your answers. Reread the parts of the lesson that cover the topics you don't understand.

Reading Check

1. Define What was Democritus's definition of an atom?

Atomic Theories	
Democritus	**1.** Atoms are small, solid objects that cannot be divided, created, or destroyed. **2.** Atoms are constantly moving in empty space. **3.** Different types of matter are made of different types of atoms. **4.** The properties of the atoms determine the properties of matter.
John Dalton	**1.** All matter is made of atoms that cannot be divided, created, or destroyed. **2.** During a chemical reaction, atoms of one element cannot be converted into atoms of another element. **3.** Atoms of one element are identical to each other but different from atoms of another element. **4.** Atoms combine in specific ratios.

Interpreting Tables

2. Identify Which philosopher in the table above proposed that atoms move in empty space?

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Reading Check

3. Describe According to Democritus, what might atoms of gold look like?

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Reading Check

4. Explain Why didn't many early philosophers believe Democritus's ideas?

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Democritus proposed that different types of matter are made from different types of atoms. For example, he said that smooth matter is made of smooth atoms. He also proposed that nothing was between these atoms except empty space. Democritus's ideas are summarized in the table above.

Although Democritus had no way to test his ideas, many of his ideas are similar to the way scientists describe the atom today. Because Democritus's ideas did not conform to the popular opinion and could not be tested, they were open for debate. The philosopher Aristotle challenged Democritus's ideas.

Aristotle

Aristotle (384–322 B.C.) did not believe that empty space exists. Instead, he favored the more popular idea—that all matter is made of fire, water, air, and earth. Aristotle was highly respected. As a result, his ideas were accepted. Democritus's ideas about atoms were not studied again for more than 2,000 years.

Dalton's Atomic Model

In the late 1700s, English schoolteacher and scientist John Dalton (1766–1844) looked again at the idea of atoms. Technology and scientific methods had advanced a great deal since Democritus's time. Dalton made careful observations and measurements of chemical reactions. He combined data from his own scientific research with data from the research of other scientists to propose the atomic theory. The table at the top of this page lists ways that Dalton's atomic theory supported some of the ideas of Democritus.

The Atom

Today, scientists agree that matter is made of atoms with empty space between and within them. What is an atom? Imagine dividing a piece of aluminum foil into smaller and smaller pieces. At first, you could cut the pieces with scissors. But eventually, the pieces would be too small to see. They would be much smaller than the smallest piece you could cut with scissors. This small piece is an aluminum atom. An aluminum atom cannot be divided into smaller aluminum pieces. *An* **atom** *is the smallest piece of an element that still represents that element.*

The Size of Atoms

Just how small is an atom? Atoms of different elements are different sizes. However, all are very, very small. You cannot see atoms even with most microscopes. Atoms are so small that about 7.5 trillion carbon atoms could fit into the period at the end of this sentence.

Seeing Atoms

Scientific experiments confirmed that matter is made of atoms long before scientists could see atoms. However, in 1981, a high-powered microscope, called a scanning tunneling microscope (STM), was invented. With this microscope, scientists could see individual atoms for the first time. An STM uses a tiny, metal tip to trace the surface of a piece of matter. The result is an image of atoms on the surface.

Even today, scientists still cannot see inside an atom. However, scientists have learned that atoms are not the smallest particles of matter. In fact, atoms are made of much smaller particles. What are these particles? How did scientists discover them if they could not see them?

Thomson—Discovering Electrons

Not long after Dalton's findings, another English scientist, named J.J. Thomson (1856–1940), made some important discoveries. Thomson and other scientists of that time worked with cathode ray tubes. If you have seen a neon sign, an older computer monitor, or the color display on an ATM screen, you have seen a cathode ray tube.

Thomson's cathode ray tube was a glass tube with pieces of metal, called electrodes, attached inside the tube. The electrodes were connected to wires. The wires were connected to a battery.

Key Concept Check

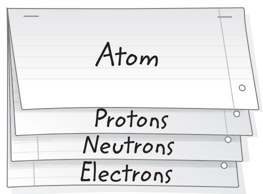
5. Apply What is a copper atom?

Key Concept Check

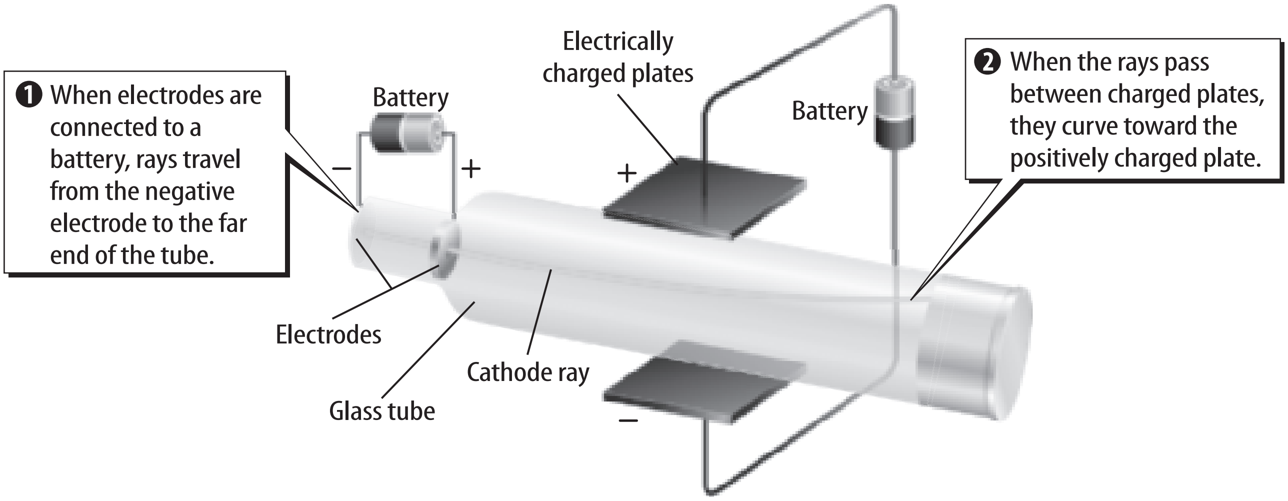
6. Describe How would you describe the size of an atom?

FOLDABLES®

Make a layered book to organize your notes and diagrams on the parts of an atom.



Thomson's Cathode Ray Tube Experiment



Visual Check

7. Recognize Did the ray in the experiment bend toward the plate with the positive charge or the plate with the negative charge?

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Reading Check

8. Analyze If the rays were positively charged, what would Thomson have observed as they passed between the plates?

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Thomson's cathode ray tube is shown above. Thomson removed most of the air from the tube. When he passed electricity through the wires, greenish-colored rays traveled from one electrode to the other end of the tube. What were these rays made of?

Negative Particles

Scientists called these rays cathode rays. Thomson wanted to know if these rays had an electric charge. To find out, he placed two plates on opposite sides of the tube. As shown in the figure above, one plate was positively charged. The other plate was negatively charged. As the cathode rays passed between the plates, the rays bent toward the positively charged plate and away from the negatively charged plate. Recall that opposite charges attract each other, and like charges repel each other. Thomson concluded that cathode rays are negatively charged.

Parts of Atoms

Through more experiments, Thomson learned that these rays were made of particles that had mass. The mass of one of these particles was much smaller than the mass of the smallest atoms. This was surprising information to Thomson. Until then, scientists understood that an atom is the smallest particle of matter. But these rays were made of particles that were even smaller than atoms.

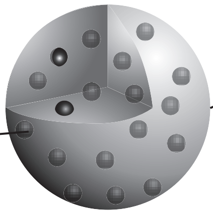
Metal Atoms Where did these small, negatively charged particles come from? Thomson proposed that these particles came from the metal atoms in the electrode. Thomson discovered that electrodes made of any kind of metal produced identical rays.

Charged Particles Putting these clues together, Thomson concluded that cathode rays were made of small, negatively charged particles. He called these particles electrons. *An* **electron** *is a particle with one negative charge (1–).* Atoms are neutral, or not electrically charged. Therefore, Thomson proposed that atoms also must contain a positive charge that balances the negatively charged electrons.

Thomson's Atomic Model

Thomson used this information to propose a new model of the atom. Instead of a solid, neutral sphere that was the same throughout, Thomson's model of the atom contained both positive and negative charges. He proposed that an atom was a sphere with a positive charge evenly spread throughout. Negatively charged electrons were mixed through the positive charge, similar to the way chocolate chips are mixed in cookie dough. The figure below shows this model.

Thomson's Atomic Model



Rutherford—Discovering the Nucleus

The discovery of electrons stunned scientists. Ernest Rutherford (1871–1937) was Thomson's student. He later had students of his own. Rutherford's students experimented with Thomson's model and discovered yet another surprise.

Rutherford's Predicted Result

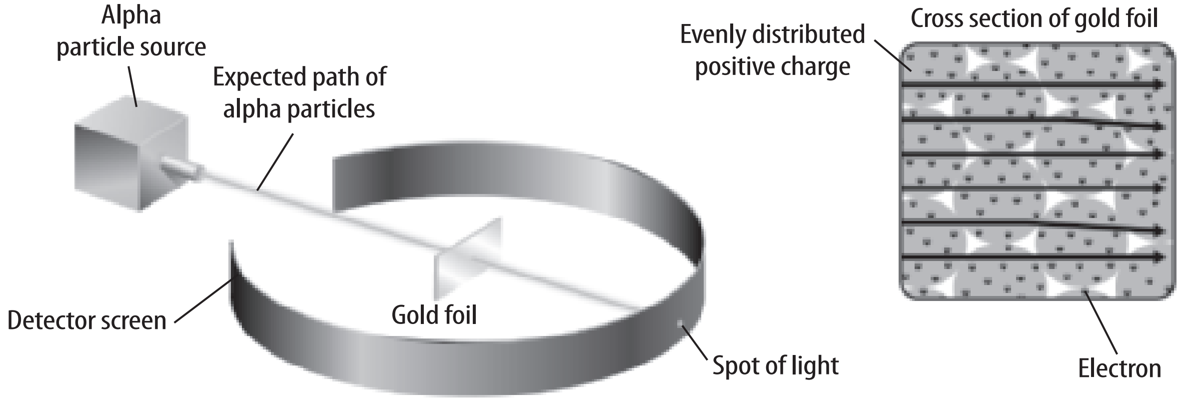
Imagine throwing a baseball into a pile of table tennis balls. The baseball likely would knock the table tennis balls away and continue moving in a mostly straight line. This is similar to what Rutherford's students expected to see when they shot alpha particles into atoms. Alpha particles are dense and positively charged. Because they are so dense, only another dense particle could deflect the path of an alpha particle. According to Thomson's model, the positive charge of the atom was too spread out and not dense enough to change the path of an alpha particle. Electrons wouldn't affect the path of an alpha particle because electrons didn't have enough mass. Rutherford expected the alpha particles to travel straight without changing direction.

Reading Check
9. Differentiate How did Thomson's atomic model differ from Dalton's atomic model?

Visual Check
10. Describe How were the positive and negative charges arranged in Thomson's model?

Reading Check
11. Explain why Rutherford's students did not think an atom could change the path of an alpha particle.

Rutherford's Predicted Result



Visual Check

12. Draw Highlight the expected path of the alpha particles.

Key Concept Check

13. Interpret Given the results of the gold foil experiment, how do you think an actual atom differs from Thomson's model?

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Visual Check

14. Recognize What do the dots on the screen indicate?

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The figure above shows the result that Rutherford's students expected. They expected the positive alpha particles to travel straight through the foil without changing direction.

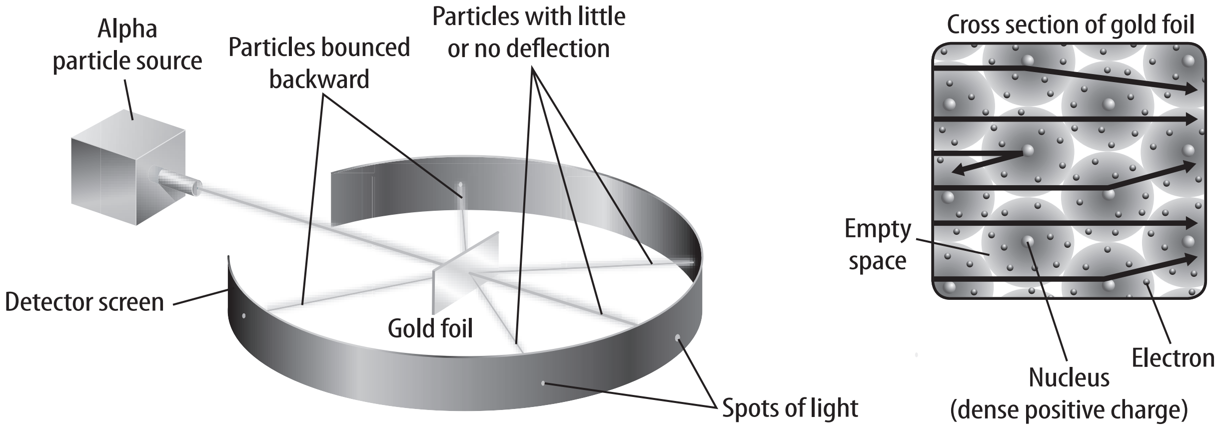
The Gold Foil Experiment

The students placed a source of alpha particles near a thin piece of gold foil made of gold atoms. A screen surrounded the gold foil. When an alpha particle struck the screen, it created a spot of light. The students could determine the path of the particles from the spots of light on the screen.

The Surprising Result

The figure below shows what the students observed. Most of the particles did indeed travel through the foil in a straight path. However, a few particles struck the foil and bounced off to the side. And one particle in 10,000 bounced straight back! Rutherford later said that this result was almost as surprising as if you fired a bullet at a piece of tissue paper and it came back and hit you. The alpha particles must have struck something dense and positively charged inside the atom. Thomson's model had to be refined.

The Surprising Result

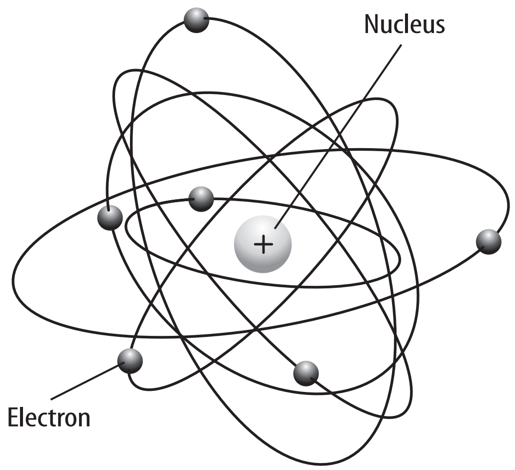


Rutherford's Atomic Model

The result showed that most alpha particles traveled through the foil in a straight path. Therefore, Rutherford concluded that atoms are made mostly of empty space. The alpha particles that bounced backward must have hit a dense, positive mass. Rutherford concluded that *most of an atom's mass and positive charge is concentrated in a small area in the center of the atom called the* **nucleus.**

Rutherford's atomic model, shown below, contains a small, dense, positive nucleus. Further research showed that the nucleus was made up of positively charged particles called protons. *A* **proton** *is an atomic particle that has one positive charge (1+).* Negatively charged electrons move in the empty space surrounding the nucleus.

Rutherford's Atomic Model



Reading Check

15. Explain How did Rutherford explain the observation that some of the alpha particles bounced directly backward?

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Visual Check

16. Identify In Rutherford's model, what makes up most of the area of an atom? (Circle the correct answer.)

a. the nucleus

b. electrons

c. empty space

Discovering Neutrons

The modern model of the atom was beginning to take shape. James Chadwick (1891–1974) worked with Rutherford and also researched atoms. He discovered that in addition to protons, the nucleus contained neutrons. *A* **neutron** *is a neutral particle that exists in the nucleus of an atom.*

Bohr's Atomic Model

Rutherford's model explained much of his students' experimental evidence. However, the model could not explain several observations.

Colors of Light Scientists noticed that if they heated certain elements in a flame, the elements gave off specific colors of light. Each color of light had a specific amount of energy. Where did this light come from?

Bohr's Experiments Niels Bohr (1885–1962), another student of Rutherford, proposed an answer to why certain elements heated in a flame give off light of specific colors. He studied hydrogen atoms because they contain only one electron.

Bohr experimented with adding electric energy to hydrogen and studying the energy that was released. His experiments led to a revised atomic model, shown in the figure below.

Visual Check

17. Predict According to Bohr's atomic model, what would happen to the electron in a hydrogen atom if you added energy to the atom?

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Electrons in the Bohr Model

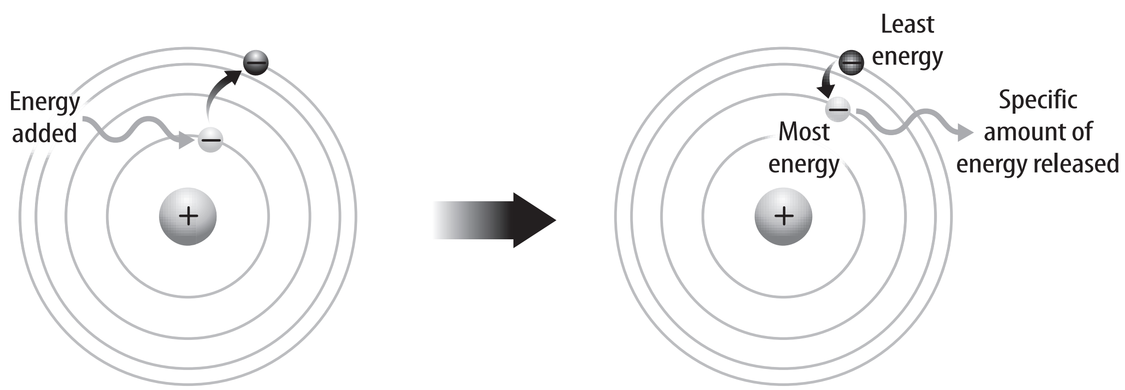
Bohr proposed that electrons move in circular orbits, or energy levels, around the nucleus. Electrons in an energy level have a specific amount of energy. Electrons closer to the nucleus have less energy than electrons that are farther away from the nucleus.

When energy is added to an atom, electrons gain energy and move from a lower energy level to a higher energy level. When the electrons return to the lower energy level, they release a specific amount of energy as light. This is the light that appears when elements are heated.

Bohr's Atomic Model

When energy is added to a hydrogen atom, its electron moves from the lowest energy level to one of the higher energy levels. In this example, it moves to the fourth level.

When the electron moves from the fourth level to one of the three lower levels, a specific amount of energy is released, depending on which level it moves to.



Key Concept Check

18. Contrast How did Bohr's atomic model differ from Rutherford's?

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Limitations of the Bohr Model

Bohr reasoned that if his model were accurate for atoms with one electron, it would be accurate for atoms with more than one electron. However, this was not the case.

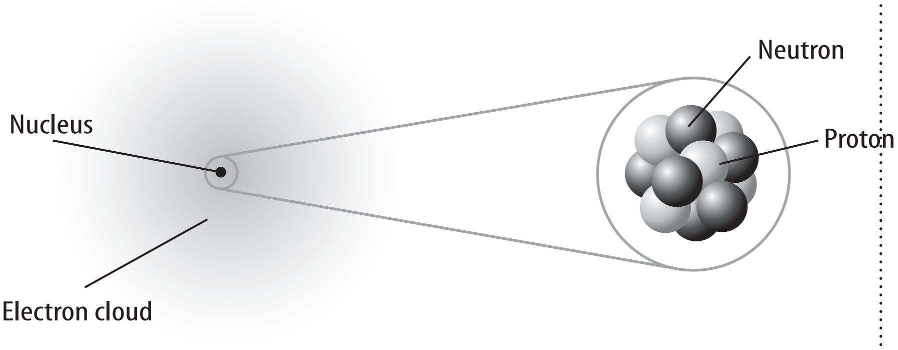
More research confirmed that electrons do have specific amounts of energy, but energy levels are not arranged in circular orbits. How do electrons move in an atom?

The Modern Atomic Model

In the modern atomic model, electrons form an electron cloud. *An* **electron cloud** *is an area around an atomic nucleus where an electron is most likely to be located*. Imagine taking a time-lapse photograph of bees around a hive. You might see a blurry cloud. The cloud might be denser near the hive than farther away because the bees spend more time near the hive.

In a similar way, electrons constantly move around the nucleus. It is impossible to know the speed and the exact location of an electron at a given moment. Instead, scientists only can predict the likelihood that an electron is in a particular location. The electron cloud, shown in the figure below, is mostly empty space. It represents the likelihood of finding an electron in a given area. The darker areas represent areas where electrons are more likely to be located.

The Modern Atomic Model



Quarks

You have read that atoms are made of smaller parts—protons, neutrons, and electrons. Are these particles made of even smaller parts? Scientists have discovered that electrons are not made of smaller parts. However, research has shown that protons and neutrons are made of smaller particles. Scientists call these particles quarks. Scientists theorize that there are six types of quarks. They named these quarks up, down, charm, strange, top, and bottom. Protons are made of two up quarks and one down quark. Neutrons are made of two down quarks and one up quark.

As you have read, the model of the atom has changed over time. The current model also might change with the invention of new technology that aids the discovery of new information.

Key Concept Check
19. Summarize How has the model of the atom changed over time?

Visual Check
20. Consider Why do you think this model of the atom doesn't show the electrons?

After You Read

Mini Glossary

atom: the smallest piece of an element that still represents that element

electron: a particle with one negative charge (1–)

electron cloud: an area around an atomic nucleus where an electron is most likely to be located

neutron: a neutral particle that exists in the nucleus of an atom

nucleus: a small, positively charged area in the center of an atom that contains most of the atom's mass

proton: an atomic particle that has one positive charge (1+)

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes how neutrons and protons are related to a nucleus.

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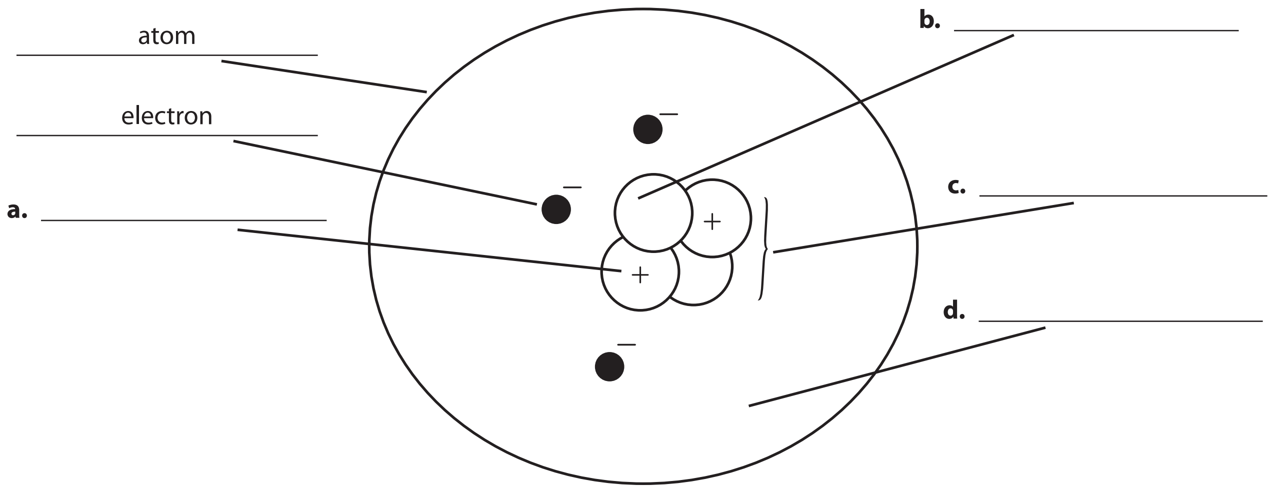
2. Name the parts of the modern atomic model in the diagram using the terms provided.

electron cloud **neutron** **nucleus** **proton**



3. On the lines below, write one question from your partner's quiz that helped you learn an important concept about atoms. Then write the answer.

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What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON