LEARN ABOUT

Atoms

FIND OUT

- what matter is made of
- what atoms are made of and what holds them together

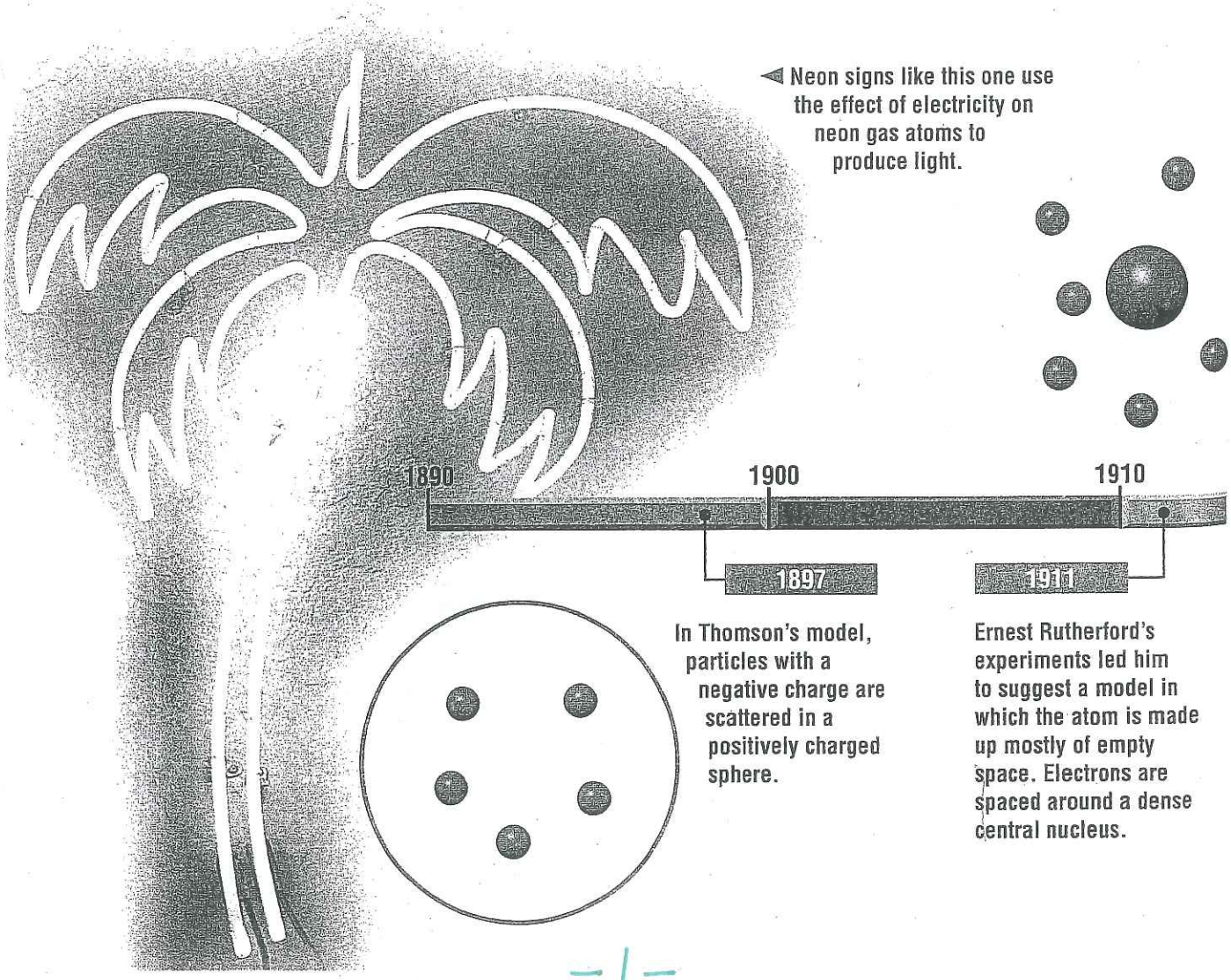
VOCABULARY

atom
nucleus
proton
neutron
electron
atomic number

Matter Is Made of Atoms

Suppose you cut a piece of pure gold in half and then cut one of the smaller pieces in half. How many times could you keep on cutting the pieces in half? What would you end up with? For thousands of years, people tried to answer these questions. Democritus (dih•MAHK•ruh•tuhs), a philosopher who lived in Greece about 2400 years ago, suggested that there would finally be a piece that could not be divided any further. Democritus called this tiny piece an atom. An **atom** is the smallest unit of a pure substance that still has the properties of that substance.

Not until the early 1800s were scientists able to use experiments—not just ideas—to study the nature of matter. An English chemist named John Dalton was the first scientist to use experiments to support the *atomic theory*—the theory that matter is made of atoms.



◀ Neon signs like this one use the effect of electricity on neon gas atoms to produce light.

In Thomson's model, particles with a negative charge are scattered in a positively charged sphere.

Ernest Rutherford's experiments led him to suggest a model in which the atom is made up mostly of empty space. Electrons are spaced around a dense central nucleus.

We now know just how tiny atoms are. A single grain of table salt may contain more than 2,000,000,000,000,000,000 (2 billion billion) atoms.

Dalton hypothesized that atoms are the smallest particles of matter and that they cannot be divided. Near the end of the 1800s, J. J. Thomson showed that atoms are made of even smaller particles. The parts of atoms are called *subatomic particles.*

Thomson made a model of an atom to explain his findings. His model was the first to include subatomic particles. The diagrams on these pages show how the structure of atoms was modeled as new information became available.

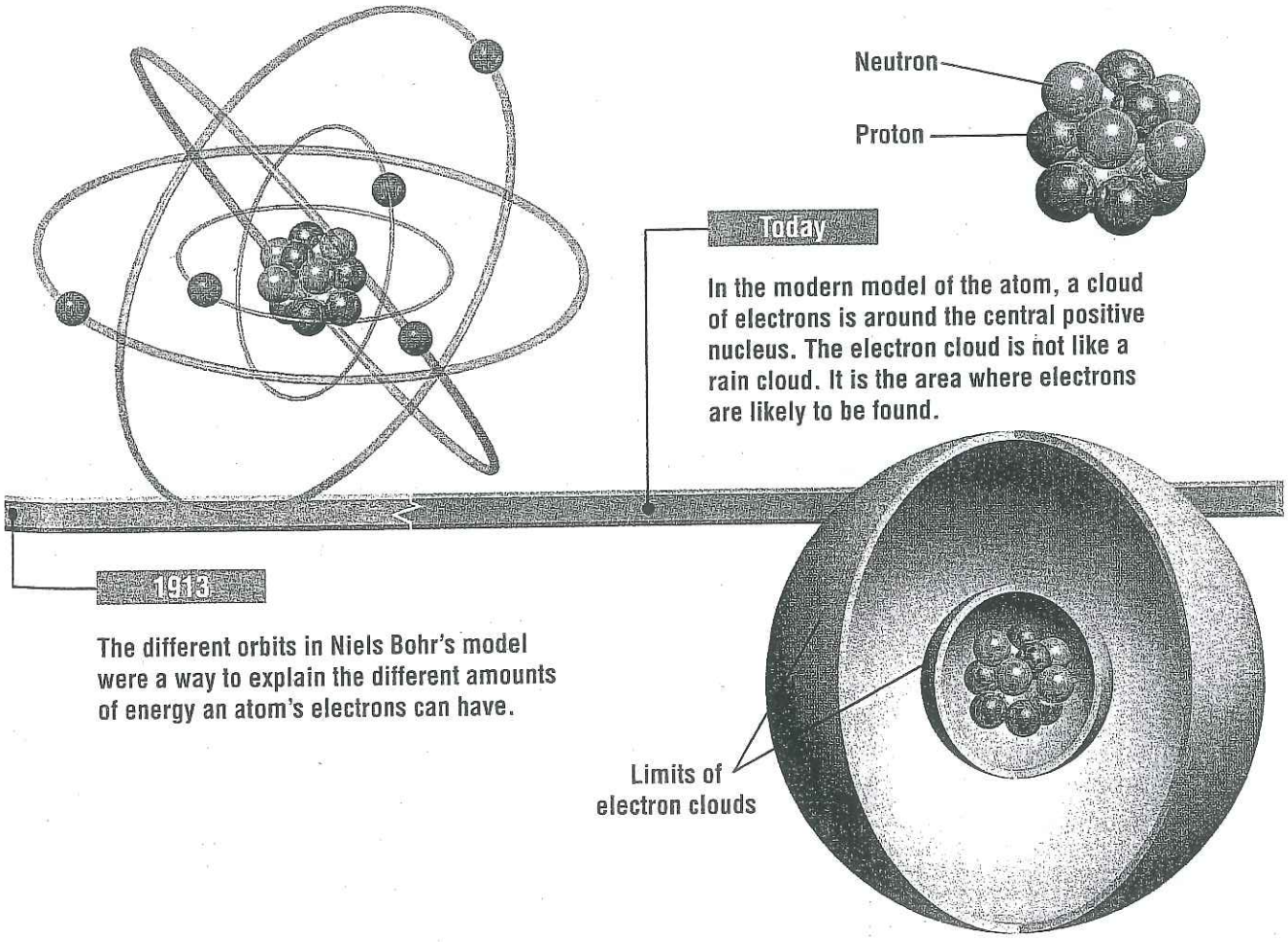
At the center of any atom is its **nucleus**. The nucleus has a positive electric charge. The nucleus is made up of at least one subatomic particle and usually several that are close together.

Every atom's nucleus contains at least one proton. A **proton** is a subatomic particle that has a positive electric charge. As you can see in the model, an atom's nucleus may also contain another kind of subatomic particle, the neutron. A **neutron** is a subatomic particle that has the same mass as a proton but no electric charge.

An **electron** is a negatively charged subatomic particle. Electrons are in constant motion around the nucleus. They have a mass much smaller than that of a proton or neutron. When electrons were first discovered to be in motion, scientists made models in which electrons orbited the nucleus. These models look something like the orbits of the planets in our solar system.

Modern models of atoms show electrons in a cloud around the nucleus. The outer edges of the cloud define the size of the atom.

✓ **What are the subatomic particles that make up an atom?**



The Nucleus

The first evidence that an atom has a nucleus came from Ernest Rutherford's experiments in 1911. The investigation in this lesson was a simple model of Rutherford's experiment.

Rutherford fired positively charged particles at a very thin sheet of gold foil. Most of the particles traveled straight through the gold. Only a few changed direction or bounced back.

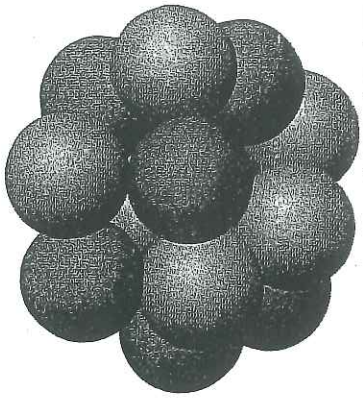
Rutherford inferred that the particles could travel straight through the gold only if they did not hit anything. Because most of the particles did not hit anything, it made sense that most of the gold was empty space. In fact, the diameter of the nucleus of an atom is about $\frac{1}{10{,}000}$ the diameter of an atom. If you think of the nucleus of an atom as being the size of a tennis ball, the whole atom would be a sphere with a diameter of about half a mile.

Although the nucleus takes up so little of the space in an atom, it accounts for more than 99.9 percent of the mass of the atom. A proton or neutron has nearly 2000 times the mass of an electron. Because the nucleus has a small volume and most of the mass of the atom, it is extremely dense.

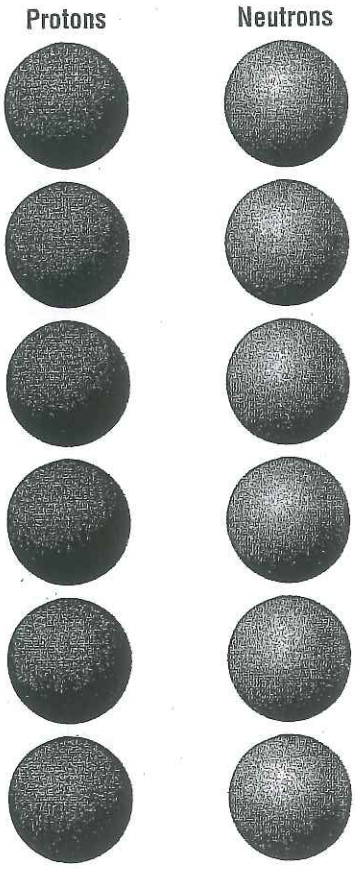
The number of protons in an atom determines what kind of atom it is. For example, any atom with only one proton is a hydrogen atom. Any atom with eight protons is an oxygen atom.

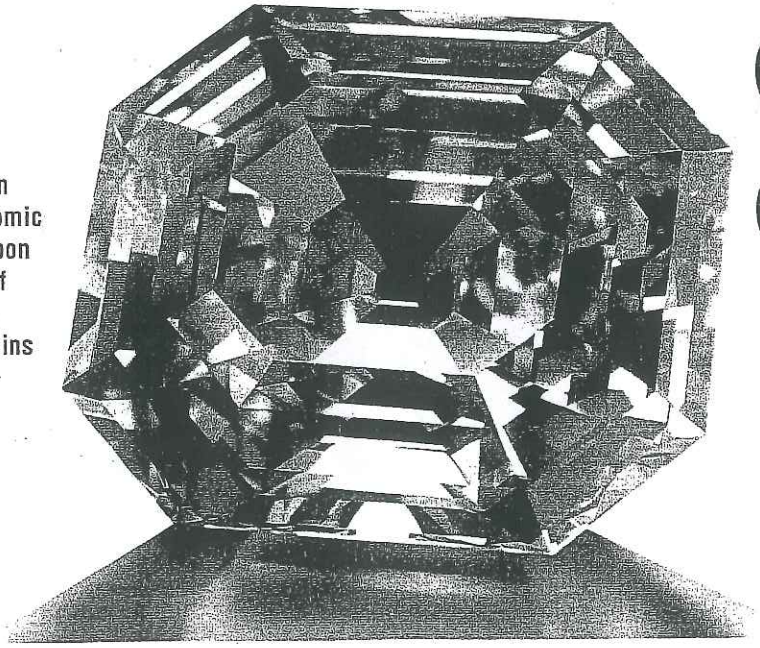
The number of protons in an atom is called the **atomic number**. For example, the atomic number of hydrogen is 1 and the atomic number of oxygen is 8.

✓ **What determines the atomic number of a substance?**



The nucleus of a carbon-12 atom contains six protons and six neutrons. Its atomic number—the number of protons—is 6. ►





Diamonds are made of carbon atoms. The atomic number of carbon is 6, so each of the atoms in a diamond contains six protons. ►

Isotopes

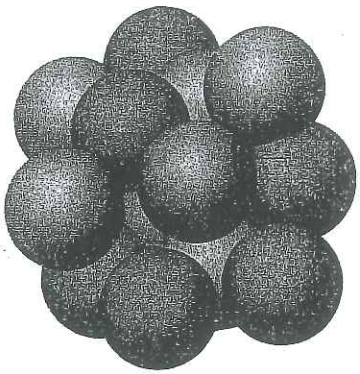
All the atoms of a substance have the same atomic number because they all have the same number of protons. But atoms of the same substance may have different masses. This difference is not due to protons, and the electrons account for hardly any of an atom's mass. The difference in mass occurs because atoms can have different numbers of neutrons.

Atoms that have the same number of protons but different numbers of neutrons are called *isotopes*. You can think of isotopes as different varieties of an element. Isotopes of the same element behave in similar ways but have slightly different structures. See the hydrogen example below.

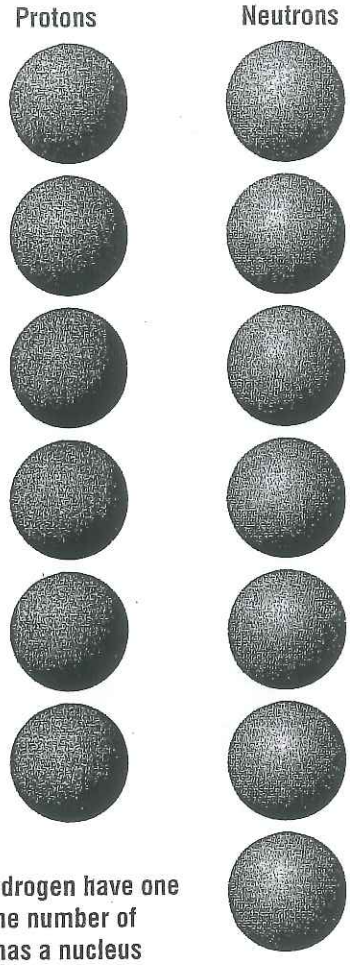
The mass of an atom is so small that scientists don't measure it in grams. Instead, they use *atomic mass units*, or amu. Every proton has the same mass, and it is defined to be 1 amu. Neutrons have almost exactly the same mass as protons, so a neutron also has a mass of 1 amu. The *atomic mass* of a substance is equal to the total number of protons and neutrons of an atom. So, different isotopes of an element have different atomic masses.

The atomic masses of hydrogen isotopes are 1 amu, 2 amu, and 3 amu. An isotope's name is usually the name of the substance followed by the number of particles in the nucleus. For example, the isotope of hydrogen that has only a proton in the nucleus could be called hydrogen-1.

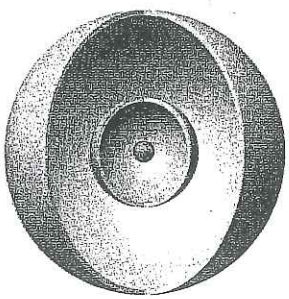
✓ **Do isotopes that have the same atomic number have the same atomic mass? Explain.**



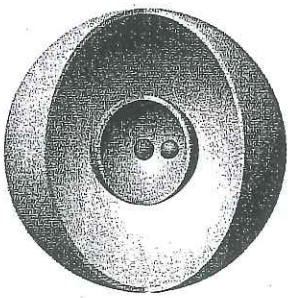
The nucleus of a carbon-13 atom contains six protons and seven neutrons. Like all carbon isotopes, its atomic number is 6. Is its atomic mass smaller or greater than the atomic mass of carbon-12?



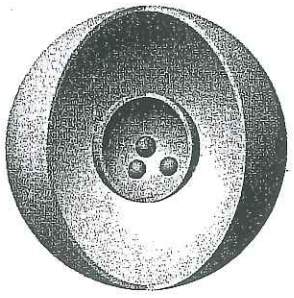
All three isotopes of hydrogen have one proton. They differ in the number of neutrons. Hydrogen-1 has a nucleus that has only a proton. Hydrogen-2 has a nucleus with one proton and a neutron. Hydrogen-3 has a nucleus with one proton and two neutrons. ▼



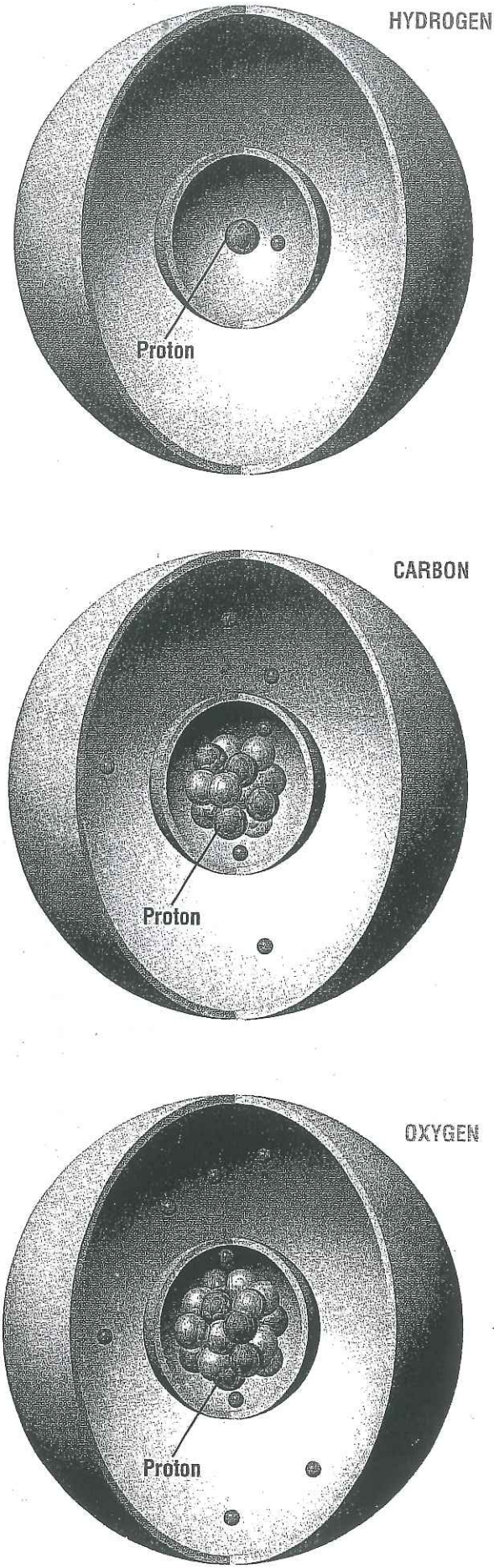
Hydrogen-1



Hydrogen-2



Hydrogen-3



Charges in Atoms

Protons have a positive electric charge. Electrons have a negative electric charge. Although their charges are opposite, a proton has the same amount of charge as an electron.

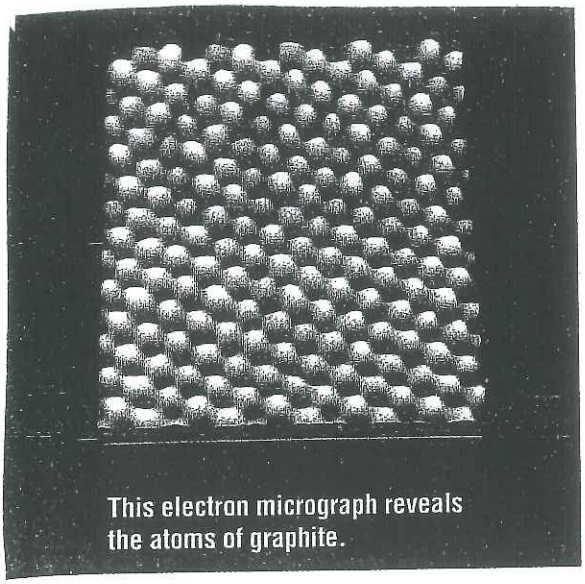
The charges of subatomic particles have a lot to do with the structure of an atom. Opposite charges attract, so the positive charge of the protons holds the negatively charged electrons in the cloud around the nucleus. Electrons closest to the nucleus are attracted more strongly than those farther away.

Opposite charges attract each other, but like charges repel each other. So why don't the protons in the nucleus repel each other? Overpowering the force of repulsion is the *strong nuclear force.* This force has an effect over only a tiny distance—a distance not much greater than the radius of a proton. The strong nuclear force has the same strength regardless of the charge of a nuclear particle. It holds the protons and neutrons together in the nucleus. Without this force, our whole universe would not hold together.

In an atom with the same number of protons and electrons, the charges balance and the atom is neutral. But sometimes one or more electrons are added to or removed from an atom. When that happens, the whole atom has an electric charge, and the atom is called an *ion.* Atoms that gain electrons become negatively charged ions. Atoms that lose electrons become positively charged ions.

✓ **A neutral atom of oxygen has eight protons. How many electrons does it have?**

◀ **In a neutral atom, the number of protons equals the number of electrons. The charge of the nucleus is equal to the charge of the cloud of electrons. These diagrams show neutral atoms of hydrogen, carbon, and oxygen.**



This electron micrograph reveals the atoms of graphite.

Summary

An atom is the smallest unit of a substance that still has the properties of that substance. The nucleus of an atom contains protons and neutrons and is surrounded by electrons. The atoms of different substances have different numbers of protons. Isotopes are atoms of the same substance that have different numbers of neutrons. Protons are positively charged, and electrons are negatively charged. Neutral atoms have the same number of protons and electrons.

Review

1. How are protons and neutrons alike, and how are they different?
2. Which of the subatomic particles is the smallest?
3. What are isotopes?
4. **Critical Thinking** If there is a difference between a substance's atomic number and its atomic mass, which measure must be the larger number?
5. **Test Prep** Which of the following is NOT a subatomic particle?
   - A electron
   - B ion
   - C proton
   - D neutron

LINKS

MATH LINK

Problem Solving Suppose an atom has an atomic number of 10 and an atomic mass of 21 amu. How many neutrons does the atom have?

WRITING LINK

Informative Writing—Report Write a short essay for your teacher about the early models of atoms. Tell how those models contributed to scientific knowledge even though they were incomplete.

LANGUAGE ARTS LINK

Origin of Words Research the origin of the word *atom*, and find out why the name is used appropriately.

TECHNOLOGY LINK

Learn more about how scientists use their knowledge of atoms to develop new technology, by watching *Atomic Laser* on the **Harcourt Science Newsroom Video.**