POWER BASICS®

Chemistry

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UNIT 2

Properties of Matter

LESSON 5: The Structure of Matter

GOAL: To learn about the internal structure of atoms

WORDS TO KNOW

atomic mass	coulombs	molecular mass
atomic mass unit	electrons	neutrons
atomic number	isotopes	protons
cathode-ray tube	mass number	

Dalton's Atomic Theory

The ancient Greek philosopher Leucippus and his follower, Democritus, proposed more than 2000 years ago that matter is made up of extremely small particles that cannot be divided further. Democritus called these bits of matter *atomos*. *Atomos* means "indivisible" and is the source of our word *atoms* today.

Many contemporaries of Leucippus and Democritus, including Plato and Aristotle, did not accept the idea that matter was made up of particles that have distinct properties of their own. Instead, they believed that all matter was uniform in composition, no matter how small the piece of matter.

These two opposing ideas were not tested until the 1700s. That is when scientists began doing careful experiments on the changes that matter undergoes. In 1808, an English schoolteacher named John Dalton proposed his own atomic view of matter. It has since become known as Dalton's atomic theory.

Dalton's atomic theory can be summarized as follows:

1. All matter is composed of tiny particles called atoms.

2. All atoms of a given element are identical. They all have the same mass, size, and chemical properties.

3. All atoms of a given element are distinct from all atoms of any other element. The mass, size, and chemical properties of the atoms of one element are different from the mass, size, and chemical properties of the atoms of any other element.

4. Chemical compounds form when atoms combine in whole-number ratios. A pure compound has the same combination of atoms, no matter how it was prepared. For example, pure water always contains two hydrogen atoms chemically joined to one oxygen atom. If some compound contains a different combination of hydrogen and oxygen atoms, then it is not water. It is a different compound altogether.

5. Atoms cannot be created from nothing or destroyed in a chemical reaction. Instead, atoms retain their identities but change the way they are combined or arranged.

PRACTICE 20: Dalton's Atomic Theory

Decide if each statement that follows is true (**T**) or false (**F**). Write the correct letter on each line.

_____ **1.** The Greek word *atomos* means "indivisible" and is the source of the word *atoms* today.

_____ **2.** Dalton's atomic theory is named for the ancient Greek philosopher Leucippus and his follower, Democritus.

_____ **3.** According to Dalton's atomic theory, all atoms of a given element are identical.

_____ **4.** According to Dalton's atomic theory, a pure compound has a different combination of atoms depending on how it was prepared.

_____ **5.** According to Dalton's atomic theory, atoms cannot be created from nothing or destroyed in a chemical reaction.

_____ **6.** According to Dalton's atomic theory, the mass, size, and chemical properties of the atoms of one element are different from the mass, size, and chemical properties of the atoms of any other element.

_____ **7.** According to Dalton's atomic theory, atoms CAN be created or destroyed in a chemical reaction.

_____ **8.** According to Dalton's atomic theory, chemical compounds form when atoms combine in whole-number ratios.

Electrons, Protons, and Neutrons

Although matter is composed of atoms, atoms are not as indivisible as Democritus or Dalton suggested. Thanks to the careful experiments of physicists such as J. J. Thomson, Robert Millikan, Hans Geiger, Ernest Marsden, Ernest Rutherford, and James Chadwick, it is now known that atoms are made up of electrons, protons, and neutrons.

Electrons are negatively charged particles that have very little mass but take up most of the volume of an atom. **Protons** are positively charged particles that have more than 1800 times the mass of an electron, but take up very little of the volume of an atom. The charge on a proton is equal and opposite to the charge on an electron. **Neutrons** have no charge and have a mass that is only slightly greater than the mass of a proton. Electrons, protons, and neutrons are called subatomic particles because they are the building blocks of atoms. The mass of a subatomic particle is measured in kilograms. The charge of a subatomic particle is measured in units called **coulombs.**

Name	Symbol	Charge	Mass
Electron	e	-1.6022×10^{-19} coulomb	9.1094×10^{-31} kg
Proton	p	$+1.6022 \times 10^{-19}$ coulomb	1.6726×10^{-27} kg
Neutron	n	0	1.6749×10^{-27} kg

J. J. Thomson's experiments in 1897 measured the ratio of the electron's mass to the electron's charge. Thomson was unable to determine the exact mass of an electron, but he estimated it to be less than $\frac{1}{1000}$ as much as hydrogen, the lightest element known. Thomson's experiments showed that atoms were divisible into smaller particles, after all.

Robert Millikan's experiments in 1909 determined the exact charge on an electron. From his value for the charge, and Thomson's value for the electron's mass-to-charge ratio, Millikan was able to determine the mass of an electron:

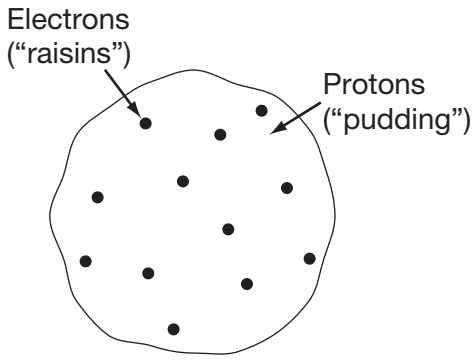
$$\text{Mass of electron} = \frac{\text{mass}}{\text{charge} \times \text{charge}}$$

$$= \left(5.686 \times \frac{10^{-12}\,\text{kg}}{\text{coulomb}}\right)(1.602 \times 10^{-19}\ \text{coulomb})$$

$$= 9.109 \times 10^{-31}\ \text{kg}$$

At this point, scientists knew two things about atoms. First, they knew that atoms are electrically neutral overall. Second, they knew that atoms contain negatively charged electrons. In order to be electrically neutral overall, atoms must also contain some positively charged particles (protons) to balance the negative charge of the electrons. Thomson proposed that atoms could be thought of as positively charged spheres of matter in which electrons are embedded like raisins in plum pudding.

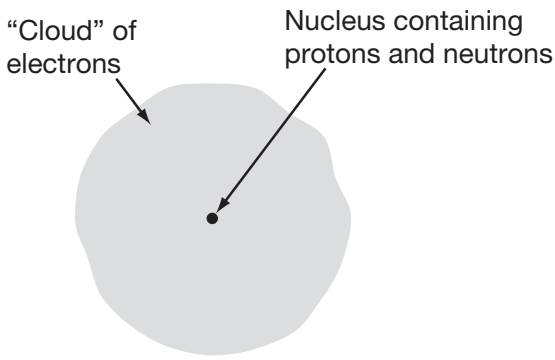
Another way to think of Thomson's "plum pudding" model of the atom is to imagine a chocolate-chip cookie. The chocolate chips are the electrons, and the cookie is the "positively charged sphere of matter." Together, the cookie and the chips make up an atom.



Thomson's "Plum Pudding" Model

The experiments of Hans Geiger and Ernest Marsden in Ernest Rutherford's lab in 1911 suggested, however, that the protons are concentrated in the core of the atom, not spread throughout the atom. Rutherford proposed that an atom consists of a positively charged nucleus surrounded by a cloud of electrons. The nucleus is the central core of the atom where most of the mass is. Thus, the protons of an atom are in the nucleus. Rutherford's theory is often called the nuclear model of the atom.

In the nuclear model of the atom, the volume of the cloud of electrons is huge compared to the volume of the nucleus. In fact, if a golf ball were the nucleus of an atom, the electron cloud would measure 3 miles across. The mass of an electron is so small compared to the mass of a proton that the electron cloud is mostly empty space.



Rutherford's Nuclear Model

Finally, in 1932, James Chadwick conducted experiments that led to the discovery of the neutron. Because the mass of a neutron is slightly greater than the mass of a proton, neutrons must be located in the nucleus, too.

PRACTICE 21: Electrons, Protons, and Neutrons

Decide if each statement that follows is true (**T**) or false (**F**). Write the correct letter on each line.

_____ **1.** The nucleus of an atom is where the electrons are.

_____ **2.** The nucleus of an atom is where the protons and neutrons are.

_____ **3.** The mass of a neutron is slightly greater than the mass of a proton, and the mass of a proton is more than 1800 times greater than the mass of an electron.

_____ **4.** J. J. Thomson's experiments measured the ratio of the electron's mass to the electron's charge.

_____ **5.** Hans Geiger proposed the "plum pudding" model of the atom.

_____ **6.** James Chadwick discovered the electron.

_____ **7.** In Rutherford's nuclear model of the atom, protons have most of the mass, but electrons have most of the volume of an atom.

_____ **8.** Robert Millikan's experiments determined the exact charge on an electron.