How big are atoms?

Atoms are very small

An atom and its parts are much smaller than a meter. The diameter of an atom is 10^{-10} (0.0000000001) meter, whereas an electron is smaller than 10^{-18} (0.000000000000000001) meter. Comparatively, this means that an electron is 10 million times smaller than an atom! The diameter of a nucleon (a proton or neutron) is a distance that is equal to one fermi. This unit (equal to 10^{-15} meter) is named for Enrico Fermi, an Italian-born physicist who studied the nucleus of the atom. For his work with neutrons, he received the Nobel Prize for physics in 1938.

Most of the atom is empty space

You may be surprised to learn that most of the atom is actually empty space: If the atom was the size of your classroom, then the nucleus would be the size of a grain of sand in the center of the room.

Particle	Diameter (meters)
atom	10^{-10}
nucleus	[illegible]
proton	[illegible]
neutron	[illegible]
electron	[illegible]

Figure 18.3: *Diameters of [illegible] atom and its subatomic particles*

John Dalton and the atomic theory

As early as 400 BC, Greek philosophers proposed the **atomic theory**. This theory states that all matter is composed of tiny particles called atoms. Many centuries later, English chemist and physicist John Dalton (1766-1844) was one of the first scientists to set out to gather evidence for the idea. Dalton was a remarkable person. Born into a family too poor to send him to school, young John educated himself and, at age 12, became a schoolteacher. He grew to be one of the leading scientists of his time.

In 1808, Dalton published a detailed atomic theory that contained the following important points:

1. Each element is composed of extremely small particles called atoms.
2. All atoms of a given element are identical.
3. Atoms of different elements have different properties, including mass and chemical reactivity.
4. Atoms are not changed by chemical reactions, but merely rearranged into different compounds.
5. Compounds are formed when atoms of more than one element combine.
6. A compound is defined by the number, type (element), and proportion of the constituent atoms.

Dalton's atomic theory laid the groundwork for later atomic models, and over time, his original theory has been expanded and updated.

Weather & atomic th[illegible]

One of John Dal[illegible] was weather [illegible] kept [illegible] records for 57 years [illegible] led him to study gas[illegible] studied the evaporation [illegible] water into the air a[illegible] to understand that [illegible] increased gas pressu[illegible] these observations [illegible] and from other exper[illegible] he gathered evidence [illegible] the structure of matte[illegible]

The changing model of the atom

The current model of the atom represents our current understanding of atomic structure. This model is one of a series of models constructed by people as they learned new information about atoms. New information enabled people to update and change their ideas about how the atom is constructed.

The name *atom* comes from Democritus, a Greek philosopher (circa 460-370 BC) who proposed that matter is made up of small particles, which he called atoms, from the Greek word *atomos*, or indivisible. His model describes atoms as small particles that differ in size and shape, that combine in different configurations, and that are constantly in motion. Many of Democritus' ideas were based on logical thinking.

The idea that theories need to be supported by evidence—often gathered in carefully controlled experiments—became important in the 1600s. Then scientists began to design experiments to support or disprove ideas proposed by earlier thinkers such as Democritus. John Dalton (see previous page) was a chemist who experimented with different gases. His careful measurements gave him repeatable evidence that matter is made up of atoms. His model of the atom is a tiny hard sphere (figure 18.4).

The idea that atoms might contain smaller particles came about through a series of observations of ray tubes, devices that were early versions of fluorescent and neon lights. Julius Plucker (1801-) and William Crooks, an English physicist and chemist (1832-1919), and his countryman and fellow physicist Joseph John Thomson (1856-1940) conducted many of these experiments. They showed that different gases placed in the tubes generated streams of particles and conducted current.

From these experiments Thomson identified the electron, which carries a negative charge. Thomson knew that atoms were electrically neutral, so he proposed that the atom was a positive sphere with negative electrons embedded in it like raisins in a bun (figure 18.5). The positive sphere and the negative electrons had an equal and opposite amount of charge, so the atom was neutral.

In England, physicists Ernest Rutherford (1871-1937), Hans Geiger (1882-) and Ernest Marsden (1889-1970), used high-speed, lightweight atoms called particles (generated by radioactive material), to bombard very thin pieces of gold foil. Most of the particles passed through the foil and hit a screen behind it. But surprisingly, some of them bounced back. They must have hit areas of the foil with greater density!

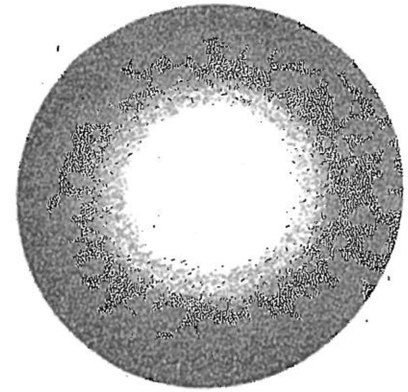

Figure 18.4: *Dalton's model of the atom. He thought atoms were tiny, hard spheres.*

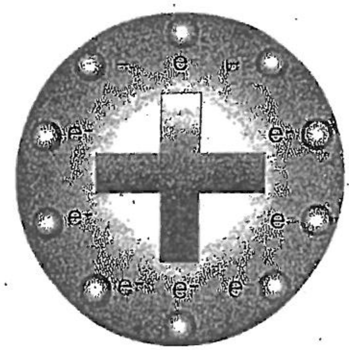

Figure 18.5: *The Thomson model of the atom. The atom is a positive sphere with negative electrons embedded in it. Thomson discovered the electron.*

Rutherford hypothesized that an atom must be made up of mostly empty space, allowing most of the alpha particles to pass through the foil. In the center of the atom, he suggested, was a tiny core called a nucleus, which contained positively- charged protons. This is where most of the mass must be found. The lighter electrons occupied the area between the nucleus and the edge of the atom. However, Rutherford did not have enough information to describe the electrons' location more fully.

Danish physicist Niels Bohr (1885-1962) used information about the nature of the emission of light by heated objects to update Rutherford's model. He described electrons as moving around the nucleus in fixed orbits that have a set amount of energy (figure 18.6). Bohr's model of the electron orbits is still used in many analyses of the atom. However, other 20th century experiments have shown that radiating waves can behave like particles in motion, and particles in motion can behave like waves.

In 1923, Louis de Broglie (1892-1987), a French physicist, showed how to analyze a moving particle as a wave. In 1926, Austrian physicist Erwin Schrödinger (1887-1961) built on de Broglie's work and treated electrons as three-dimensional waves. He developed a mathematical description of electrons in atoms that is called the quantum mechanical model of the atom. It is also called the electron cloud model, because his mathematical description cannot be described easily either in words or pictures, so a cloud represents the probability of electron position.

There still remained a serious problem with the atomic model, a problem Rutherford had identified so many years earlier: missing mass. In 1932, James Chadwick, an English physicist working in Rutherford's laboratory, finally solved the problem. He identified the third important subatomic particle, the neutron. Chadwick (1891-1974) based his work on earlier experiments by French physicists Irene and Frederic Joliot-Curie.

Understanding what is inside an atom has motivated many thousands of scientists and thinkers. What some of them discovered along the way changed the world, influencing not only theoretical spheres such as many of the sciences, philosophy, logic, and other areas, but also those subjects' practical applications. So many new technological developments of the late 20th century have been made possible by atomic research that the present era is often referred to as the "atomic age."

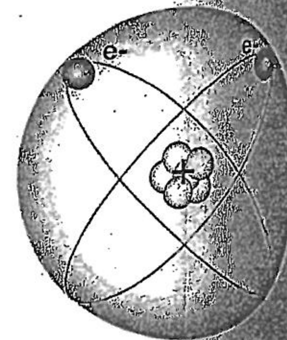

Figure 18.6: *The Bohr model of the atom. Electrons move ... nucleus in fixed orbits.*

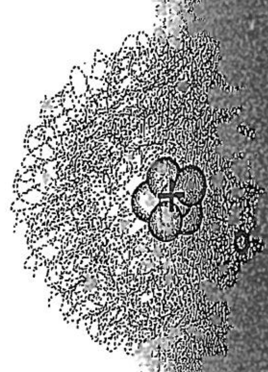

Figure 18.7: *Electrons ... Schrödinger model of the atom ... model is also called the electron ... model. The cloud represents ... probable locations of an electron ...*

8.2 Compa

As you know, some s elements. You alread helium, silver, gold, a

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How people figured ou stories in science. It br chemists who studied l

Atomic Number

The number of protons determines an element

Can you change the number of protons?

What is the atomic number?

Re: neu thai ator All diff prot Ther chem The Beca chem atom Atom 11, labora