CONCEPT 3

An atom is made up of electrons, neutrons, and protons

Activity

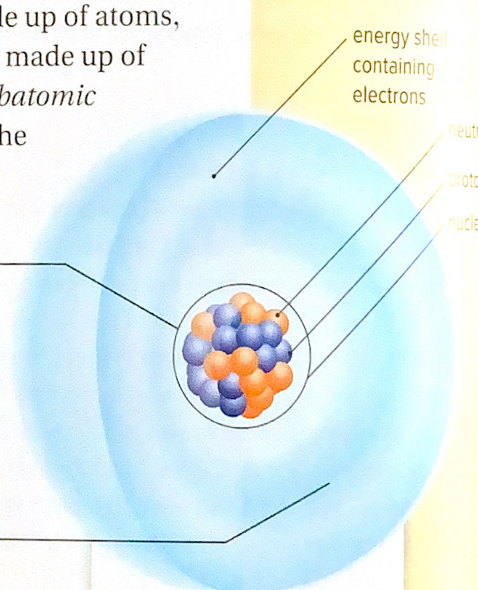
Cutting It Down to Size

Can you cut a piece of paper down to the size of an atom? Atoms vary in size, but a mid-sized atom is about 0.00000002 cm in diameter.

1. Take a strip of paper that is 25 cm long.
2. Predict how many times you would have to cut the strip in half to get a piece that is about 0.00000002 cm wide.
3. Start cutting. How many times were you able to cut your paper in half? How many more times would you have to cut to get your paper to the size of an atom?

atom the smallest particle of an element that retains the properties of that element

Today we know a lot about the nature and structure of atoms. An **atom** is defined as the smallest particle of an element that retains the properties of that element. All matter is made up of atoms, and atoms themselves are made up of smaller particles called *subatomic particles*. Key features of the atom are summarized in **Figure 2.31**.



nucleus

- The nucleus is the tiny region at the centre of the atom.
- The nucleus of most hydrogen atoms contains one proton.
- The nucleus of all other atoms contains both protons and neutrons.
- The number of protons in a nucleus determines the charge of the nucleus and the identity of an atom.

electron energy shell

- The region that electrons occupy accounts for well over 99.99 percent of the volume of an atom.
- Electrons occupy specific regions called energy levels that surround the nucleus.
- An electron is not like a fast-moving particle racing around the nucleus. It is more like a spread-out cloud of negative charge that exists in the whole region all at once.

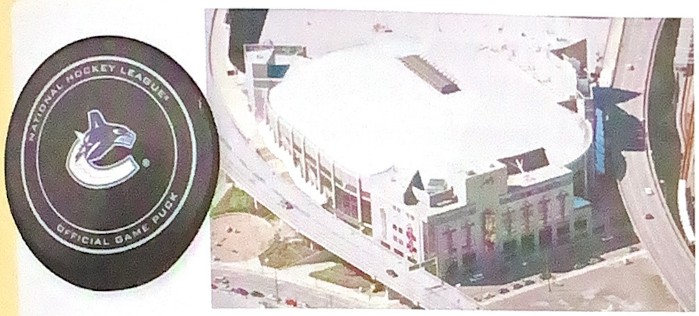
Figure 2.31 This model of the atom will help you explain the observations you make about matter in your study of chemistry.

Electric Charge

Electric charge comes in two types: positive and negative. Protons have a positive charge (1+ each), and electrons have a negative charge (1– each). The positive charge of the protons in the nucleus attracts the surrounding electrons. Neutrons have no charge. Atoms have equal numbers of protons and electrons, and so overall an atom is uncharged or neutral.

The Size of an Atom

Atoms are incredibly small. Suppose you enlarged everything on Earth so that an atom would become as big as a large apple. At this new scale, an apple would be as big as Earth!



The Size of the Nucleus Compared with an Atom

If a nucleus were the size of a hockey puck sitting at centre ice, the whole atom would include the entire rink, the seats, the building, and the surrounding streets and walkways or parking lot.

The Nuclear Force

Nuclei include multiple positively charged particles—protons—that are very close together. Normally, charged particles that have the same charge repel one another very strongly. But a force called the *nuclear force* (also called the *strong force*) acts within the nucleus to hold protons and neutrons together. It is very strong across very short distances—strong enough to counteract the repulsion between protons, keeping the nucleus from flying apart.

Connect to Investigation 2-I on pages 170–171

Subatomic Particles

Name	Symbol	Electric Charge	Relative Mass	Location in the Atom
proton	p^+	1+	1836	nucleus
neutron	n^0	0	1837	nucleus
electron	e^-	1–	1	surrounding the nucleus

Before you leave this page . . .

1. What are the three subatomic particles?
2. Compare and contrast the electron and the proton.
3. Use an analogy to describe the size or composition of an atom.
4. What does the existence of a nuclear force explain?

CONCEPT 4

Atomic theory continues to develop.

Activity

Atomic Theory in the Future

Do you think atomic theory is likely to change in the future? Write a brief blog post explaining your position. Support your ideas with examples.

According to Dalton's theory, atoms were indivisible and indestructible. Then Thomson discovered the electron and Rutherford discovered the nucleus, which was later found to be made up of neutrons and protons. The atom was not indivisible at all: it was made up of even smaller particles—*subatomic particles*. As scientists continued to study matter throughout the 20th century, they discovered that some of these subatomic particles were made up of still smaller particles.

Quarks

You may have heard the term "quark" before, perhaps in the title of CBC Radio's science program, Quirks and Quarks. According to current theories, quarks are *elementary particles*, meaning that they cannot be split apart into smaller particles. There are six different types, called *flavours* (really!) of quarks. They are classified based on their properties, which include mass and electric charge, and have the following creative names: *up*, *down*, *strange*, *charm*, *top*, and *bottom*.

Protons and neutrons are known as composite particles. As shown in Figure 2.32, they are both made up of quarks. Protons and neutrons also contain elementary particles called gluons. These act as a "glue" that binds quarks to one another.

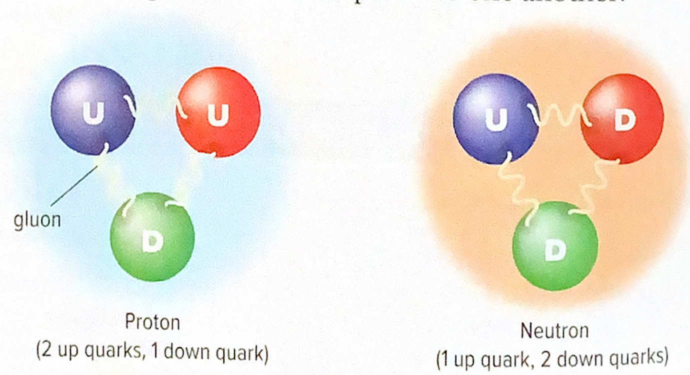


Figure 2.32 Protons and neutrons are made up of smaller elementary particles.

Leptons

Unlike protons and neutrons, electrons are themselves elementary particles. They are a type of elementary particle called *leptons*. Like quarks, leptons come in six flavours, as shown in Table 2.4. The key difference between quarks and leptons is that quarks experience the strong force, while leptons do not.

Table 2.4 Characteristics of Leptons

Lepton	Description
electron	• The electron is the lepton found in atoms. • Compared to the electron, muon and tau particles have the same charge (1^-) but a much greater mass.
muon	
tau	
electron neutrinos	• Neutrinos are very difficult to detect. They have no charge and are nearly massless. • Trillions of them pass through our bodies each second. • Neutrinos are produced by high-energy processes such as nuclear reactions in the Sun.
muon neutrinos	
tau neutrinos	

Research Continues

Today, engineers and scientists continue to work together to probe the atom even further. One local example, the TRIUMF cyclotron, is shown in Figure 2.33. Located in Vancouver, the cyclotron was built to research the particles that make up matter. Electromagnets in the cyclotron accelerate protons to extraordinary speeds. The resulting proton beam is allowed to collide with various materials, and specialized detectors provide data about the products of the collisions.

Figure 2.33 The TRIUMF cyclotron is a particle accelerator that produces a high-speed beam of protons. People come to Vancouver from all over the world to use it to run experiments.

Extending the Connections

Beyond the Atom

Choose one of these terms or another of your choice to research: dark matter, antimatter, the Higgs boson, superstring theory, or quantum mechanics.

Before you leave this page . . .

1. Describe the structure of a proton.
2. Compare neutrinos and electrons.