An atom is composed of two regions. The center of the atom, which is called the **nucleus,** contains subatomic particles called **protons** and **neutrons**. The atom's outermost region holds subatomic particles known as **electrons**. Electrons orbit around the nucleus, as Figure 2.4. illustrates. All atoms, except hydrogen, contain protons, electrons, and neutrons. Most hydrogen atoms contain only one proton and one electron and have no neutrons.

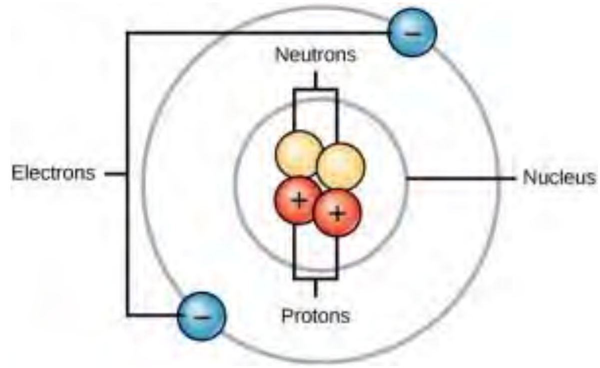

Figure 2.4 Atoms are made up of protons and neutrons located within the nucleus, and electrons surrounding the nucleus. (credit: Clark et al./Biology 2E OpenStax)

Protons and neutrons have approximately the same mass, about 1.67×10^{-24} grams. Scientists arbitrarily define this amount of mass as one atomic mass unit (amu). Although similar in mass, protons and neutrons differ in their electrical charge. A proton is positively charged; whereas, a neutron is uncharged (Table 2.2). The number of neutrons in an atom contributes significantly to its mass, but not to its charge. Electrons are much smaller in mass than protons or neutrons, weighing only 9.11×10^{-28} grams. As a result, electrons do not contribute significantly to an element's overall atomic mass. When calculating atomic mass, it is customary to ignore the mass of any electrons and calculate the atom's mass based on the number of protons and neutrons alone.

Each electron has a negative charge equal to the positive charge of a proton. In uncharged, neutral atoms, the number of electrons orbiting the nucleus is equal to the number of protons inside the nucleus. The atom will have no charge because the positive and negative charges cancel each other out.

Protons, Neutrons, and Electrons

	Charge	**Mass (amu)**	**Location**
Proton	+	1	nucleus
Neutron	0	1	nucleus
Electron	–	0	orbitals

Table 2.2 shows the characteristics of the three subatomic particles. (credit: Clark et al./Biology 2E OpenStax)

Most of an atom's volume, greater than 99 percent, is empty space. With all this empty space, one might ask why solid objects do not just pass through one another. The reason this does not occur is due to the electrons that surround all atoms. Electrons are negatively charged, and negative charges of different objects repel one another, preventing this from occurring.

Atomic Number and Mass

Atoms of each element contain a unique number of protons and electrons. The number of protons determines an element's **atomic number**, which scientists use to distinguish one element from another. For example, hydrogen has an atomic number of 1, meaning it has one proton. Helium has an atomic number of 2, meaning it has two protons in its nucleus (Figure 2.2). All atoms of a particular element will have the same number of protons. The number of neutrons an atom has is variable. **Isotopes** are different atoms of the same element that vary only in their number of neutrons. Together, the number of protons and neutrons determines an element's **atomic mass number** (Figure 2.5). Note that we disregard the small contribution of mass from electrons in calculating the mass number. We can use this approximation of mass to easily calculate how many neutrons an element has by subtracting the number of protons from the mass number.

An element's isotopes will all have slightly different mass numbers. When scientists determine the atomic mass of an element, they take the mean of the mass numbers for all its naturally occurring isotopes. Often, the resulting number contains a fraction. For example, the atomic mass of chlorine (Cl) is 35.45 because chlorine is composed of several isotopes, most with atomic mass 35 (17 protons and 18 neutrons) and some with atomic mass 37 (17 protons and 20 neutrons).

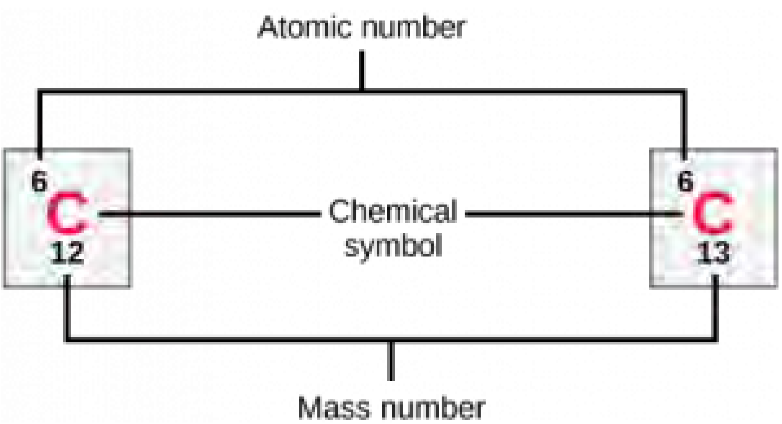

Figure 2.5 Carbon has an atomic number of six, and two stable isotopes with mass numbers of twelve and thirteen, respectively. Its relative atomic mass is 12.011 (credit: Clark et al./Biology 2E OpenStax)

Check your knowledge

How many neutrons does carbon-12 have?

How many neutrons does carbon-13 have?

If an atom has 13 electrons, 13 protons, and 13 neutrons, what is its atomic mass?

Answer: C-12 (6 neutrons); C-13 (7 neutrons)
Atomic mass of 26 amu.

Isotopes

As mentioned above, isotopes are different forms of an element that have the same number of protons but a different number of neutrons. Hydrogen-1 contains one proton, zero neutrons, and one electron. Hydrogen-2, also called deuterium, has one proton, one neutron, and one electron (Figure 2.6). These two alternate forms of hydrogen are isotopes. Some elements, such as carbon, potassium, and uranium, have naturally occurring isotopes. Carbon-12 contains six protons, six neutrons, and six electrons; therefore, it has a mass number of 12. Carbon-14 contains six protons, eight neutrons, and six electrons; its atomic mass is 14. Some isotopes are unstable and will lose neutrons, other subatomic particles, or energy to form more stable atoms. These are called **radioactive isotopes** or radioisotopes.

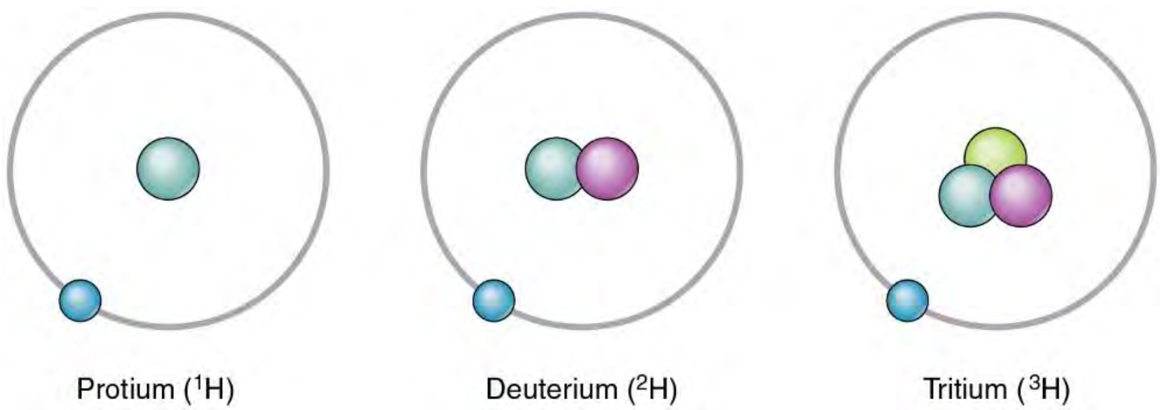

Figure 2.6 Isotopes of Hydrogen. (credit: Betts et al./Anatomy and Physiology OpenStax)

Evolution in Action

Carbon Dating

Carbon-14 (^{14}C) is a naturally occurring radioisotope that is created in the atmosphere by cosmic rays. This is a continuous process, so more ^{14}C is always being created. As a living organism develops, the relative level of ^{14}C in its body is equal to the concentration of ^{14}C in the atmosphere. When an organism dies, it is no longer ingesting ^{14}C, so the ratio will decline. ^{14}C decays to ^{14}N by a process called beta decay; it gives off energy in a relatively slow process (Figure 2.7).

After approximately 5,730 years, only one-half of the starting concentration of ^{14}C will have been converted to ^{14}N. The time it takes for half of the original concentration of an isotope to decay to its more stable form is called its half-life. Because the half-life of ^{14}C is long, it is used to age dead organisms or objects, such as fossils.