Electron Shells and the Bohr Model

There is a connection between the number of protons in an element, the atomic number, and the number of electrons it has. In all electrically neutral atoms, the number of electrons is the same as the number of protons. Each element, at least when electrically neutral, has a characteristic number of electrons equal to its atomic number.

In 1913, Danish scientist Niels Bohr (1885–1962) developed an early model of the atom. The Bohr model describes an atom as having a central nucleus containing protons and neutrons. The electrons orbit the nucleus at specific distances (Figure 2.10). These orbits form electron shells or energy levels, which are a way of visualizing the number of electrons in the outermost shells. These energy levels are designated by a number and the symbol "n." For example, 1n represents the first energy level located closest to the nucleus.

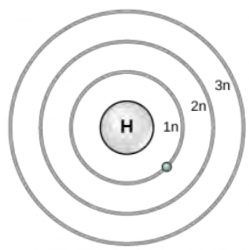

Figure 2.10 Bohr model. (credit: Clark et al./Biology 2E OpenStax)

Electrons fill orbitals in a consistent order. First, they fill the orbitals closest to the nucleus. Once the closest orbitals are filled, electrons fill orbitals of increasing energy further from the nucleus. The number of electrons in the outermost energy level determines the atom's energetic stability, how reactive or nonreactive an atom is. These electrons determine the tendency of an atom to form chemical bonds with other atoms. Remember, when atoms form chemical bonds with one another, molecules are formed.

Under standard conditions, atoms fill the inner shells first, often resulting in a variable number of electrons in the outermost shell. The innermost shell has a maximum of two electrons, but the next electron shell can hold up to eight electrons. This is known as the octet rule, which states, except for the innermost shell, that atoms are more stable energetically when they have eight electrons in their **valence shell**, the outermost electron shell. Figure 2.11 shows examples of some neutral atoms and their electron configurations. Notice that in Figure 2.11, helium has a complete outer electron shell, with two electrons filling its first and only shell. Similarly, neon has a complete outer 2n shell containing eight electrons. Because these atoms have full outer shells, they are considered stable or non-reactive. In contrast, chlorine has seven and sodium one electron in their outer shells, and therefore they are unstable and more likely to react and form chemical bonds with other atoms. An atom's reactivity is governed by its need to be more energetically stable, which results if their valence shells are full.

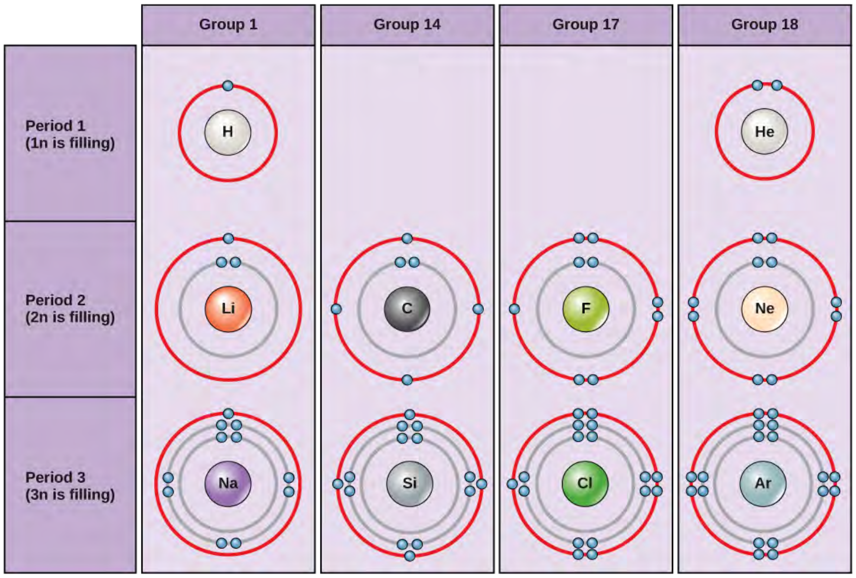

Figure 2.11 Bohr diagrams indicate how many electrons fill each principal shell. Group 18 elements (helium, neon, and argon) have a full outer or valence shell. A full valence shell is the most stable electron configuration. Elements in other groups have partially filled valence shells and gain or lose electrons to achieve a stable electron configuration. (credit: Clark et al./Biology 2E OpenStax)

Check your knowledge

An atom may give, take, or share electrons with another atom to achieve a full valence shell. Looking at the above figure, how many electrons do elements in group 1 need to lose in order to achieve a stable electron configuration?
How many electrons do elements in groups 14 need to gain in order to achieve a stable configuration?

Answers: (1), (4)

Electron Orbitals

Although useful to explain the reactivity and chemical bonding of certain elements, the Bohr model does not accurately reflect how electrons spatially distribute themselves around the nucleus. They do not circle the nucleus like the earth orbits the sun, but we find them in electron orbitals. Scientists call the area where an electron is most likely to be found its **orbital**. While the concepts of electron shells and orbitals are closely related, orbitals provide a more accurate depiction of an atom's electron configuration.

Section Summary

Matter is anything that occupies space and has mass. It is made up of atoms of different elements. All the 98 elements that occur naturally have unique qualities that allow them to combine in various ways to create compounds or molecules. Atoms, which consist of protons, neutrons, and electrons, are the smallest units of an element that retain all of the properties of that element.

Exercises

1. How many neutrons do (K) potassium-39 and potassium-40 have, respectively?

2. Magnesium has an atomic number of 12. Which of the following statements is true of a neutral magnesium atom?
   a. It has 12 protons, 12 electrons, and 12 neutrons.
   b. It has 12 protons, 12 electrons, and six neutrons.
   c. It has six protons, six electrons, and no neutrons.
   d. It has six protons, six electrons, and six neutrons.

3. Oxygen has an atomic number of 8. How many electrons would oxygen need to obtain to be considered stable?
   a. 1
   b. 2
   c. 4
   d. 8

4. An isotope of sodium (Na) has an atomic mass number of 22. How many neutrons does it have?
   a. 11
   b. 12
   c. 22
   d. 44

5. Compare and contrast protons neutrons and electrons.

Answer

1. Potassium-39 has twenty neutrons. Potassium-40 has twenty-one neutrons.
2. (a)
3. (b)
4. (a)
5. Protons, neutrons, and electrons are all subatomic particles that make up an atom. Protons, which have a positive charge, and neutrons that are electrically neutral, can be found in a defined space called the nucleus. Electrons that are negatively charged are found in orbitals that are arranged in discrete energy levels.