Chapter 16—The Atom

- The word atom comes from the word *atomos*, coined by Democritus and means "indivisible," reflecting the essence of his belief in atomism. This early Greek theory was abandoned in favor of Aristotle's continuous matter concept.
- John Dalton theorized that the *law of definite proportion* in compounds was directly related to the way particles of matter joined together. He believed these atoms were like tiny spheres surrounded by an envelope of heat. Atoms of the elements differed from each other, mainly in their masses. Atoms were indivisible and combined in different ways to form different compounds. His atomic theory was called the *core-envelope model*.
- J. J. Thomson investigated strange rays in a device called a cathode-ray tube. He discovered that they were beams of electrons. He suggested that negative electrons were embedded in positive matter in the atom, which led to the development of the *plum-pudding model*. His theory demonstrated that the atom could be divisible.
- Ernest Rutherford's *nuclear model* of the atom was a result of the gold-foil experiment in which alpha particles were directed at a piece of gold foil. Most passed through the foil, but a few were deflected, suggesting that the atom was mostly space but contained a tiny, dense nucleus.
- Niels Bohr explained the emission spectra of elements by the emission of quantized energy from electrons in the atoms as they changed energy levels. He envisioned electrons orbiting the nucleus at specific distances according to their energies, just like planets orbit the sun. He called his theory the *planetary model* of the atom.
- The modern model of the atom was developed in the first decades of the twentieth century by many physicists. The *quantum model* is similar to the planetary model, but it places electrons in subregions of space around the nucleus, called orbitals, where there is a high probability of finding electrons based on their energies.
- The three major subatomic particles are the proton, neutron, and electron.
- Protons have a mass of about 1 u, carry a single positive charge, and are located in the nucleus of every atom.
- Neutrons carry no charge and are also found in the nuclei of the atoms of most elements. They are the most massive subatomic particle, slightly more so than the proton.
- Electrons carry a single negative charge and occupy the space in the atom outside the nucleus. Their masses are about 1/1836 that of a proton.
- All the atoms of each element contain a unique number of protons in the nucleus. This number is called the element's atomic number (Z), which serves in identifying the element as well as determining many of its physical and chemical properties.

- An atom's mass number is the sum of protons and neutrons in its nucleus. The mass number identifies the isotope of an element.
- The mass of an atom is determined by the sum of the masses of its subatomic particles less the mass converted to nuclear binding energy. Atomic mass is measured in relative units called atomic mass units (u). Using this system, 1 u is 1/12 the mass of a carbon-12 atom to which all other atomic masses are compared.
- The arrangement of electrons around the nucleus of an atom is determined by the number of electrons present. Only certain numbers of electrons are allowed in a given energy level according to the rules established in the design of atoms. Energy levels signify where electrons will most likely be found.
- An atom's electron configuration is a unique arrangement of its electrons distributed among allowed energy levels.
- The study of changes that occur in atomic nuclei is called nuclear chemistry.
- Radioactivity is the emission of energetic rays and particles from unstable atomic nuclei.
- The three types of nuclear radiation are alpha (α) particles, beta (β) particles, and gamma (γ) rays.
- Gamma decay takes place when an energetic nucleus emits a gamma ray, leaving the atom unchanged except with less energy in the nucleus.
- Alpha decay takes place when a nucleus ejects an alpha particle, losing two protons and two neutrons in the process. The atom becomes an isotope of an element with an atomic number two less than the original element.
- Beta decay takes place when a nucleus ejects a nuclear electron from the decay of a neutron into a proton. This change produces an isotope of an element with an atomic number one greater than the original element, though its mass number is unchanged.
- Spontaneous fission occurs when a large nucleus splits and produces two or more smaller nuclei, which become atoms of other elements. Spontaneous fission is relatively rare in nature.
- Natural fusion is the joining of two or more small, light nuclei to form heavier nuclei, releasing far more energy than possible in a single fission event. Fusion is believed to be the nuclear reaction occurring in stars.
- The two types of nuclear bombardment reactions are nuclear fission and nuclear fusion. Fission reactions were first used in nuclear bombs, but now are the source of energy for electric power plants all over the world. Though it is not currently feasible to artificially control a fusion reaction at this time, it has the potential to be a source of unlimited energy to produce electricity.