Bohr Model of the Hydrogen Atom

The puzzle of the hydrogen-atom spectrum was solved in 1913 by the Danish physicist Niels Bohr. He proposed a hydrogen-atom model that linked the atom's electron to photon emission. According to the model, the electron can circle the nucleus only in allowed paths, or *orbits*. When the electron is in one of these orbits, the atom has a definite, fixed energy. The electron—and therefore the hydrogen atom—is in its lowest energy state when it is in the orbit closest to the nucleus. This orbit is separated from the nucleus by a large empty space where the electron cannot exist. The energy of the electron is higher when the electron is in orbits that are successively farther from the nucleus.

The electron orbits, or atomic energy levels, in Bohr's model can be compared to the rungs of a ladder. When you are standing on a ladder, your feet are on one rung or another. The amount of potential energy that you possess corresponds to standing on the first rung, the second rung, and so forth. Your energy cannot correspond to standing between two rungs because you cannot stand in midair. In the same way, an electron can be in one orbit or another, but not in between.

How does Bohr's model of the hydrogen atom explain the observed spectral lines? While in a given orbit, the electron is neither gaining nor losing energy. It can, however, move to a higher-energy orbit by gaining an amount of energy equal to the difference in energy between the higher-energy orbit and the initial lower-energy orbit. When a hydrogen atom is in an excited state, its electron is in one of the higher-energy orbits. When the electron falls to a lower energy level, a photon is emitted, and the process is called *emission.* The photon's energy is equal to the energy difference between the initial higher energy level and the final lower energy level. Energy must be added to an atom in order to move an electron from a lower energy level to a higher energy level. This process is called *absorption.* Absorption and emission of radiation in Bohr's model of the hydrogen atom are illustrated in **Figure 8.** The energy of each absorbed or emitted photon corresponds to a particular frequency of emitted radiation, $E_{photon} = h\nu$.

Based on the different wavelengths of the hydrogen line-emission spectrum, Bohr calculated the allowed energy levels for the hydrogen

Chemistry in Action
Fireflies

What kinds of reactions produce light? In this chapter, you are learning how excited atoms can produce light. In parts of the United States, summer is accompanied by the appearance of fireflies, or lightning bugs. What makes them glow? A bioluminescent chemical reaction that involves luciferin, luciferase (an enzyme), adenosine triphosphate (ATP), and oxygen takes place in the firefly and produces the characteristic yellow-green glow. Unlike most reactions that produce light, bioluminescent reactions do not generate energy in the form of heat.

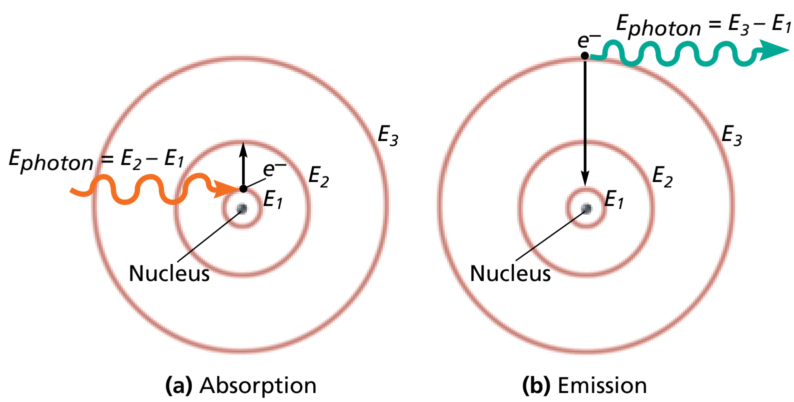

FIGURE 8 (a) Absorption and (b) emission of a photon by a hydrogen atom according to Bohr's model. The frequencies of light that can be absorbed and emitted are restricted because the electron can only be in orbits corresponding to the energies E_1, E_2, E_3, and so forth.