ADVANCED TOPICS

See "Semiconductor Doping" in **Appendix J: Advanced Topics** to learn how energy levels are used to explain electrical conduction in solids, including semiconductors.

Bohr's model further departs from classical physics by assuming that the hydrogen atom does not emit energy in the form of radiation when the electron is in any of these allowed orbits. Hence, the total energy of the atom remains constant, and one difficulty with the Rutherford model (the instability of the atom) is resolved. Bohr claimed that rather than radiating energy continuously, the electron radiates energy only when it jumps from an outer orbit to an inner one. The frequency of the radiation emitted in the jump is related to the change in the atom's energy. The energy of an emitted photon (E) is equal to the energy decrease of the atom ($-\Delta E_{atom}$). Because $\Delta E_{atom} = E_{final} - E_{initial}$, $E = -\Delta E_{atom} = E_{initial} - E_{final}$. Planck's equation can then be used to find the frequency of the emitted radiation: $E = E_{initial} - E_{final} = hf$.

In Bohr's model, transitions between stable orbits with different energy levels account for the discrete spectral lines

The lowest energy state in the Bohr model, which corresponds to the smallest possible radius, is often called the *ground state* of the atom, and the radius of this orbit is called the *Bohr radius.* At ordinary temperatures, most electrons are in the ground state, with the electron relatively close to the nucleus. When light of a continuous spectrum shines on the atom, only the photons whose energy (hf) matches the energy separation between two levels can be absorbed by the atom. When this occurs, an electron jumps from a lower energy state to a higher energy state, which corresponds to an orbit farther from the nucleus, as shown in **Figure 14(a).** This is called an *excited state.* The absorbed photons account for the dark lines in the absorption spectrum.

Once an electron is in an excited state, there is a certain probability that it will jump back to a lower energy level by emitting a photon, as shown in **Figure 14(b).** This process is known as *spontaneous emission.* The emitted photons are responsible for the bright lines in the emission spectrum.

In both cases, there is a correlation between the "size" of an electron's jump and the energy of the photon. For example, an electron in the fourth energy level could jump to the third level, the second level, or the ground state. Because Planck's equation gives the energy from one level to the next level, a greater jump means that more energy is emitted. Thus, jumps between different levels correspond to the various spectral lines that are observed. The

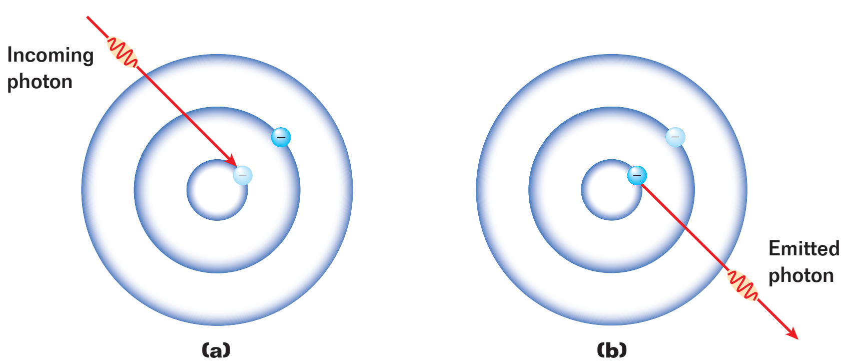

Figure 14
(a) When a photon is absorbed by an atom, an electron jumps to a higher energy level. **(b)** When the electron falls back to a lower energy level, the atom releases a photon.