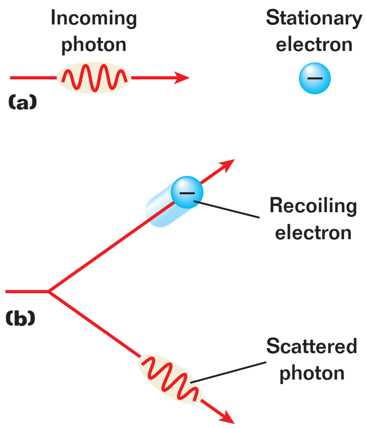

Figure 6
(a) When a photon collides with an electron, **(b)** the scattered photon has less energy and a longer wavelength than the incoming photon.

Compton shift

an increase in the wavelength of the photon scattered by an electron relative to the wavelength of the incident photon

Compton shift supports the photon theory of light

The American physicist Arthur Compton (1892–1962) realized that if light behaves like a particle, then a collision between an electron and a photon should be similar to a collision between two billiard balls. Photons should have momentum as well as energy; both quantities should be conserved in elastic collisions. So, when a photon collides with an electron initially at rest, as in **Figure 6,** the photon transfers some of its energy and momentum to the electron. As a result, the energy and frequency of the scattered photon are lowered; its wavelength should increase.

In 1923, to test this theory, Compton directed electromagnetic waves (X rays) toward a block of graphite. He found that the scattered waves had less energy and longer wavelengths than the incoming waves, just as he had predicted. This change in wavelength, known as the **Compton shift,** provides support for Einstein's photon theory of light.

The amount that the wavelength shifts depends on the angle through which the photon is scattered. Note that even the largest change in wavelength is very small in relation to the wavelengths of visible light. For this reason, the Compton shift is difficult to detect using visible light, but it can be observed using electromagnetic waves with much shorter wavelengths, such as X rays.

SECTION REVIEW

1. Describe the conflict known as the ultraviolet catastrophe. How did Planck resolve this conflict? How does Planck's assumption depart from classical physics?

2. What is the energy (in eV units) carried by one photon of violet light that has a wavelength of 4.5×10^{-7} m?

3. What effects did scientists originally think that the intensity of light shining on a photosensitive surface would have on electrons ejected from that surface? How did these predictions differ from observations?

4. How does Einstein's theory that electromagnetic waves are quantized explain the fact that the frequency of light (rather than the intensity) determines whether electrons are ejected from a photosensitive surface?

5. Light with a wavelength of 1.00×10^{-7} m shines on tungsten, which has a work function of 4.6 eV. Are electrons ejected from the tungsten? If so, what is their maximum kinetic energy?

6. **Critical Thinking** Is the number of photons in 1 J of red light (650 nm) greater than, equal to, or less than the number of photons in 1 J of blue light (450 nm)? Explain.