Rydberg and Planck Equations, Extra Exercises

1. In general, a human eye cannot detect photons of frequency greater than 750 THz (7.50×10^{14} Hz). Use the Planck equation to find the maximum photon energy necessary to stimulate receptors in the eye.

2. Blue-violet lines of the hydrogen emission spectrum are shown on page 175. Recall that *all* of the visible photons emitted by hydrogen atoms involve electron energy-level transitions from higher levels down to a final level of $n_f = 2$.
   (a) Use the Rydberg equation to show which of the blue-violet lines on the left side of the spectrum on page 175 has an initial energy level of 5.

   (b) Use algebraic substitution to combine the wave equation ($c = f\lambda$, where c is the speed of light, 3.00×10^8 m/s) and the Planck equation to determine the energy of photons of this blue-violet light in a single combined calculation.

Rydberg and Planck Equations, Extra Exercises, Solution

1. In general, a human eye cannot detect photons of frequency greater than 750 THz (7.50×10^{14} Hz). Use the Planck equation to find the maximum photon energy necessary to stimulate receptors in the eye.

$$E = hf$$

$$h = 6.63 \times 10^{-34} \text{ J/Hz}$$

$$f = 7.50 \times 10^{14} \text{ Hz}$$

$$E = \frac{6.63 \times 10^{-34} \text{ J}}{1 \text{ Hz}} \times 7.50 \times 10^{14} \text{ Hz}$$

$$E = 4.97 \times 10^{-19} \text{ J}$$

The maximum photon energy that will stimulate receptors in this eye is 4.97×10^{-19} J.

2. Blue-violet lines of the hydrogen emission spectrum are shown on page 175 of the Student Text. Recall that *all* of the visible photons emitted by hydrogen atoms involve electron energy-level transitions from higher levels down to a final level of $n_f = 2$.

   (a) Use the Rydberg equation to show which of the blue-violet lines on the left side of the spectrum on page 175 has an initial energy level of 5.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$R_H = 1.10 \times 10^7 \text{ /m}$$

$$n_f = 2 \qquad n_i = 5$$

$$\frac{1}{\lambda} = \frac{1.10 \times 10^7}{1 \text{ m}}\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$$

$$\lambda = 4.33 \times 10^{-7} \text{ m} = 433 \text{ nm}$$

The calculated wavelength of emitted light is 433 nm, which best matches the second blue-violet line from the left.

(continued)

(b) Use algebraic substitution to combine the wave equation ($c = f\lambda$, where c is the speed of light, 3.00×10^8 m/s) and the Planck equation to determine the energy of photons of this blue-violet light in a single combined calculation.

$$h = 6.63 \times 10^{-34}\ \text{J/Hz} = 6.63 \times 10^{-34}\ \text{J·s}$$

$$c = 3.00 \times 10^{8}\ \text{m/s}$$

$$E = hf$$

$$c = f\lambda \quad \text{therefore} \quad f = \frac{c}{\lambda}$$

and substituting, $$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34}\ \text{J·}\cancel{\text{s}} \times 3.00 \times 10^{8}\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{4.33 \times 10^{-7}\ \cancel{\text{m}}}$$

$$E = 4.59 \times 10^{-19}\ \text{J}$$

The energy of each photon of blue-violet light is 4.59×10^{-19} J.