6. From Equation 6.19,

$$K = \frac{e^2}{4\pi\varepsilon_0}\frac{Zz}{d} = \frac{(1.440\,\text{MeV}\cdot\text{fm})(2)(79)}{7.0\,\text{fm}} = 33\,\text{MeV}$$

7. $$d = \frac{e^2}{4\pi\varepsilon_0}\frac{Zz}{K} = \frac{(1.440\,\text{MeV}\cdot\text{fm})(2)(29)}{7.4\,\text{MeV}} = 11.3\,\text{fm}$$

14. From the Rutherford scattering formula (Eq. 6.14) the only difference between the two positions is the term depending on the angle – all other parameters are the same for the two experiments. The expected ratio between the two counting rates is then

$$\frac{N(150°)}{N(10°)} = \frac{\sin^{-4}(150°/2)}{\sin^{-4}(10°/2)} = 6.63\times10^{-5}$$

so the rate at 150° would be (11.3/s)(6.63×10^{-5}) = 7.49×10^{-4} /s.

48. The Rutherford formula will fail when the distance of closest approach is less than the combined radii of the alpha particle and aluminum nucleus. Rewriting Eq. 6.19 for the distance of closest approach in a head-on collision,

$$K = \frac{e^2}{4\pi\varepsilon_0}\frac{zZ}{d} = (1.44\ \text{MeV}\cdot\text{fm})\frac{(2)(13)}{1.9\ \text{fm} + 3.6\ \text{fm}} = 6.8\ \text{MeV}$$

Alpha particles of energy greater than 6.8 MeV will penetrate the aluminum nucleus can cause a breakdown in the Rutherford scattering formula. Such energies from radioactive decay were available in Rutherford's time.

15. The shortest wavelength is the series limit. For the Lyman series, $n_0 = 1$ and Equation 6.21 becomes

$$\lambda = (91.13 \text{ nm}) \frac{n^2}{n^2 - 1} \qquad n = 2, 3, 4, \ldots$$

which gives $\lambda = 121.51$ nm ($n = 2$), 102.52 nm ($n = 3$), 97.21 nm ($n = 4$).

18. From Figure 6.16 we see that only the Paschen series ($n_0 = 3$) has lines near 1000 nm. Using the series limit of 820.1 nm, we have from Eq. 6.21

$$1005\ \text{nm} = (820.1\ \text{nm})\frac{n^2}{n^2 - 9}$$

$$1.225(n^2 - 9) = n^2$$

Solving, we find $n = 7$, so the transition connects the $n = 7$ and $n = 3$ states.

22. The energy of the initial $n = 5$ state is $E_5 = \frac{-13.6 \text{ eV}}{25} = -0.544 \text{ eV}$. An electron in this state can make transitions to any of the lower states with $n = 4$ ($E_4 = -0.850$ eV), $n = 3$

(E_3 = –1.51 eV), n = 2 (E_2 = –3.40 eV), and n = 1 (E_1 = –13.6 eV). The transition energies are:

$$5 \rightarrow 4: \quad \Delta E = E_5 - E_4 = -0.544 \text{ eV} - (-0.850 \text{ eV}) = 0.306 \text{ eV}$$

$$5 \rightarrow 3: \quad \Delta E = E_5 - E_3 = -0.544 \text{ eV} - (-1.51 \text{ eV}) = 0.97 \text{ eV}$$

$$5 \rightarrow 2: \quad \Delta E = E_5 - E_2 = -0.544 \text{ eV} - (-3.40 \text{ eV}) = 2.86 \text{ eV}$$

$$5 \rightarrow 1: \quad \Delta E = E_5 - E_1 = -0.544 \text{ eV} - (-13.6 \text{ eV}) = 13.1 \text{ eV}$$

25. (a) The ionization energy is the magnitude of the energy of the electron. For the $n = 3$ level of hydrogen

$$|E_3| = \left|\frac{-13.6\text{ eV}}{9}\right| = 1.51\text{ eV}$$

(b) For singly ionized helium ($Z = 2$) we use Equation 6.38:

$$|E_n| = \left|\frac{(-13.6\text{ eV})Z^2}{n^2}\right| = \left|\frac{(-13.6\text{ eV})2^2}{2^2}\right| = 13.6\text{ eV}$$

(c) $$|E_n| = \left|\frac{(-13.6\text{ eV})Z^2}{n^2}\right| = \left|\frac{(-13.6\text{ eV})3^2}{4^2}\right| = 7.65\text{ eV}$$