3-34. Equation 3-24: $\lambda_m = \frac{1.24\times10^3}{V}nm = \frac{1.24\times10^3}{80\times10^3 V} = 0.016nm$

3-36. $\lambda_2 - \lambda_1 = \frac{h}{mc}(1-\cos\theta) = \frac{(6.63\times10^{-34}J\bullet s)(1-\cos110°)}{(9.11\times10^{-31}kg)(3.00\times10^8 m/s)} = 3.26\times10^{-12}m$

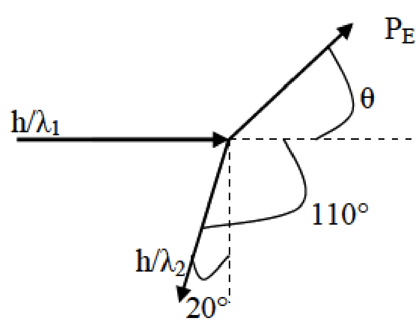
$$\lambda_1 = \frac{hc}{E_1} = \frac{(6.63\times10^{-34}J\bullet s)(3\times10^8 m/s)}{(0.511\times10^6 eV)(1.60\times10^{-19}J/eV)} = 2.43\times10^{-12}m$$

$$\lambda_2 = \lambda_1 + 3.26\times10^{-12}m = (2.43+3.26)\times10^{-12}m = 5.69\times10^{-12}m$$

$$E_2 = \frac{hc}{\lambda_2} = \frac{1240eV\bullet nm}{5.69\times10^{-3}nm} = 2.18\times10^5 eV = 0.218MeV$$

Electron recoil energy $E_e = E_1 - E_2$ (Conservation of energy)

$E_e = 0.511MeV - 0.218MeV = 0.293MeV$. The recoil electron momentum makes an angle θ with the direction of the initial photon.



$\frac{h}{\lambda_2}\cos20° = p_e\sin\theta = (1/c)\sqrt{E^2-(mc^2)^2}\sin\theta$ (Conservation of momentum)

$$\sin\theta = \frac{(3.00\times10^8 m/s)(6.63\times10^{-34}J\bullet s)\cos20°}{(5.69\times10^{-12}m)\left[(0.804MeV)^2-(0.511MeV)^2\right]^{1/2}(1.60\times10^{-13}J/MeV)}$$

$= 0.330$ or $\theta = 19.3°$

3-38. $\Delta\lambda = \lambda_2 - \lambda_1 = \Delta\lambda = \frac{h}{mc}(1-\cos\theta) = 0.01\lambda_1$ Equation 3-25

$$\lambda_1 = (100)\frac{h}{mc}(1-\cos\theta) = (100)(0.00243nm)(1-\cos 90°) = 0.243nm$$

3-39. (a) $E_1 = \frac{hc}{\lambda_1} = \frac{1240eV \bullet nm}{0.0711nm} = 1.747\times10^4 eV$

(b) $\lambda_2 = \lambda_1 + \frac{h}{mc}(1-\cos\theta) = 0.0711nm + (0.00243nm)(1-\cos 180°) = 0.0760nm$

(c) $E_2 = \frac{hc}{\lambda_2} = \frac{1240eV \bullet nm}{0.0760nm} = 1.634\times10^4 eV$

(d) $E_e = E_1 - E_2 = 1.128\times10^3 eV$

3-42. (a) Compton wavelength = $\frac{h}{mc}$

electron: $\frac{h}{mc} = \frac{6.63\times10^{-34} J\bullet s}{(9.11\times10^{-31}kg)(3.00\times10^8 m/s)} = 2.43\times10^{-12} m = 0.00243nm$

proton: $\frac{h}{mc} = \frac{6.63\times10^{-34} J\bullet s}{(1.67\times10^{-27}kg)(3.00\times10^8 m/s)} = 1.32\times10^{-15} m = 1.32 fm$

(b) $E = \frac{hc}{\lambda}$

(i) electron: $E = \frac{1240eV \bullet nm}{0.00243nm} = 5.10\times10^5 eV = 0.510MeV$

(ii) proton: $E = \frac{1240eV \bullet nm}{1.32\times10^{-6} nm} = 9.39\times10^8 eV = 939MeV$

3-52. (a) $\lambda_m T = 2.898\times10^{-3}\,m{\bullet}K \quad \therefore \quad T = \dfrac{2.898\times10^{-3}\,m{\bullet}K}{82.8\times10^{-9}\,m} = 3.50\times10^{4}\,K$

(b) Equation 3-18: $\dfrac{u(70nm)}{u(82.8nm)} = \dfrac{(70nm)^{-5}/\left(e^{hc/(70nm)kT}-1\right)}{(82.8nm)^{-5}/\left(e^{hc/(82.8nm)kT}-1\right)}$

where $\dfrac{hc}{(70nm)kT} = \dfrac{\left(6.63\times10^{-34}\,J{\bullet}s\right)\left(3.00\times10^{8}\,m/s\right)}{\left(70\times10^{-9}\,m\right)\left(1.38\times10^{-23}\,J/K\right)\left(3.5\times10^{4}\,K\right)} = 5.88$ and

$\dfrac{hc}{(82.8nm)kT} = 4.97 \qquad \dfrac{u(70nm)}{u(82.8nm)} = \dfrac{(70nm)^{-5}/\left(e^{5.88}-1\right)}{(82.8nm)^{-5}/\left(e^{4.97}-1\right)} = 0.929$

Similarly, $\dfrac{u(100nm)}{u(82.8nm)} = \dfrac{(100nm)^{-5}/\left(e^{4.12}-1\right)}{(82.8nm)^{-5}/\left(e^{4.97}-1\right)} = 0.924$

4-2. $\dfrac{1}{\lambda_{mn}} = R\left(\dfrac{1}{m^2}-\dfrac{1}{n^2}\right)$ where $m = 2$ for Balmer series (Equation 4-2)

$$\frac{1}{379.1nm} = \frac{1.097\times10^{7}\,m^{-1}}{10^{9}\,nm/m}\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

$$\frac{1}{4}-\frac{1}{n^2} = \frac{10^{9}\,nm/m}{379.1nm\left(1.097\times10^{7}\,m^{-1}\right)} = 0.2405$$

$$\frac{1}{n^2} = 0.2500 - 0.2405 = 0.0095$$

$$n^2 = \frac{1}{0.0095} \quad\rightarrow\quad n = (1/0.0095)^{1/2} = 10.3 \quad\rightarrow\quad n = 10$$

$$n = 10 \rightarrow n = 2$$

4-3. $\frac{1}{\lambda_{mn}} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$ where $m = 1$ for Lyman series (Equation 4-2)

$$\frac{1}{164.1nm} = \frac{1.097\times10^7 m^{-1}}{10^9 nm/m}\left(1 - \frac{1}{n^2}\right)$$

$$\frac{1}{n^2} = 1 - \frac{10^9 nm/m}{164.1nm\left(1.097\times10^7 m^{-1}\right)} = 1 - 0.5555 = 0.4445$$

$$n = \left(1/0.4445\right)^{1/2} = 1.5$$

No, this is not a hydrogen Lyman series transition because n is not an integer.

4-4. $\frac{1}{\lambda_{mn}} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$ (Equation 4-2)

For the Brackett series $m = 4$ and the first four (i.e., longest wavelength lines have $n = 5$, 6, 7, and 8.

$$\frac{1}{\lambda_{45}} = 1.097\times10^7 m^{-1}\left(\frac{1}{4^2} - \frac{1}{5^2}\right) = 2.468\times10^5 m^{-1}$$

$\lambda_{45} = \frac{1}{2.68\times10^5 m^{-1}} = 4.052\times10^{-6} m = 4052nm$. Similarly,

$$\lambda_{46} = \frac{1}{3.809\times10^5 m^{-1}} = 2.625\times10^{-6} m = 2625nm$$

$$\lambda_{47} = \frac{1}{4.617\times10^5 m^{-1}} = 2.166\times10^{-6} m = 2166nm$$

$$\lambda_{48} = \frac{1}{5.142\times10^5 m^{-1}} = 1.945\times10^{-6} m = 1945nm$$

These lines are all in the infrared.

4-7. $\Delta N \propto \dfrac{1}{\sin^4(\theta/2)} = \dfrac{A}{\sin^4(\theta/2)}$ (From Equation 4-6), where A is the product of the two quantities in parentheses in Equation 4-6.

(a) $\dfrac{\Delta N(10°)}{\Delta N(1°)} = \dfrac{A/\sin^4(10°/2)}{A/\sin^4(1°/2)} = \dfrac{\sin^4(0.5°)}{\sin^4(5°)} = 1.01\times10^{-4}$

(b) $\dfrac{\Delta N(30°)}{\Delta N(1°)} = \dfrac{\sin^4(0.5°)}{\sin^4(15°)} = 1.29\times10^{-6}$

4-9. $r_d = \dfrac{kq_\alpha Q}{(1/2)m_\alpha v^2} = \dfrac{ke^2 \bullet 2 \bullet 79}{E_{k\alpha}}$ (Equation 4-11)

For $E_{k\alpha} = 5.0MeV$: $r_d = \dfrac{(1.44MeV\bullet fm)(2)(79)}{5.0MeV} = 45.5fm$

For $E_{k\alpha} = 7.7MeV$: $r_d = 29.5fm$

For $E_{k\alpha} = 12MeV$: $r_d = 19.0fm$

4-10. $r_d = \dfrac{kq_\alpha Q}{(1/2)m_\alpha v^2} = \dfrac{ke^2 \bullet 2 \bullet 79}{E_{k\alpha}}$ (Equation 4-11)

$$E_{k\alpha} = \frac{(1.44MeV\bullet fm)(2)(13)}{4fm} = 9.4MeV$$

4-42. Those scattered at $\theta = 180°$ obeyed the Rutherford formula. This is a head-on collision where the α comes instantaneously to rest before reversing direction. At that point its kinetic energy has been converted entirely to electrostatic potential energy, so

$\frac{1}{2}m_\alpha v^2 = 7.7MeV = \dfrac{k(2e)(79e)}{r}$ where r = upper limit of the nuclear radius.

$$r = \frac{k(2)(79)e^2}{7.7MeV} = \frac{2(79)(1.440MeV\bullet fm)}{7.7MeV} = 29.5fm$$