

4-6. (a) $f = \pi b^2 n t$ (Equation 4-5)

For Au, $n = 5.90 \times 10^{28} \text{ atoms/m}^3$ (see Example 4-2) and for this foil

$$t = 2.0 \mu\text{m} = 2.0 \times 10^{-6} \text{ m}.$$

$$b = \frac{k q_{\alpha} Q}{m_{\alpha} v^2} \cot \frac{\theta}{2} = \frac{(2)(79) k e^2}{2 K_{\alpha}} \cot \frac{90}{2} = \frac{(2)(79)(1.44 \text{ eV} \cdot \text{nm})}{2(7.0 \times 10^6 \text{ eV})}$$

$$= 1.63 \times 10^{-5} \text{ nm} = 1.63 \times 10^{-14} \text{ m}$$

$$f = \pi (1.63 \times 10^{-14} \text{ m})^2 (5.90 \times 10^{28} / \text{m}^3) (2.0 \times 10^{-6} \text{ m}) = 9.8 \times 10^{-5}$$

$$b(45^\circ) = b(90^\circ) (\cot 45^\circ / 2) / (\cot 90^\circ / 2)$$

(b) For $\theta = 45^\circ$,

$$= b(90^\circ) (\tan 90^\circ / 2) / (\tan 45^\circ / 2)$$

$$\text{and } f(45^\circ) = 5.7 \times 10^{-4}$$

$$\text{For } \theta = 75^\circ, b(75^\circ) = b(90^\circ) (\tan 90^\circ / 2) / (\tan 75^\circ / 2)$$

$$= 2.12 \times 10^{-5} \text{ nm} = 2.12 \times 10^{-14} \text{ m}$$

$$\text{and } f(75^\circ) = 1.66 \times 10^{-4}$$

$$\text{Therefore, } \Delta f(45^\circ - 75^\circ) = 5.7 \times 10^{-4} - 1.66 \times 10^{-4} = 4.05 \times 10^{-4}$$

4-8. $b = \frac{k q_{\alpha} Q}{m_{\alpha} v^2} \cot \frac{\theta}{2}$ (Equation 4-3)

$$= \frac{k \cdot 2e \cdot Ze}{m_{\alpha} v^2} \cot \frac{\theta}{2} = \frac{(1.44 \text{ MeV} \cdot \text{fm}) Z}{E_{k\alpha}} \cot \frac{\theta}{2}$$

$$= \frac{(1.44 \text{ MeV} \cdot \text{fm})(79)}{7.7 \text{ MeV}} \cot \frac{2^\circ}{2} = 8.5 \times 10^{-13} \text{ m}$$

- 4-17. (a) $\lambda = 410.7 \text{ nm}$ is in the visible region of the spectrum, so this is a transition ending on $n = 2$ (see Figure 4-16).

$$\begin{aligned}\frac{hc}{\lambda} &= E_n - E_2 = 13.6 \text{ eV} \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \\ \frac{1240 \text{ eV} \cdot \text{nm}}{410.7 \text{ nm}} &= 13.6 \text{ eV} \left(\frac{1}{4} - \frac{1}{n^2} \right) \\ \frac{1}{n^2} &= \frac{1}{4} - \frac{1240 \text{ eV} \cdot \text{nm}}{410.7 \text{ nm} (13.6 \text{ eV})} = 0.0280 \\ n &= \left(\frac{1}{0.0280} \right)^{1/2} = 6\end{aligned}$$

- (b) This is the Balmer Series

4-19. (a) $a_\mu = \frac{\hbar^2}{\mu_\mu k e^2} = \frac{\mu_e}{\mu_\mu} \cdot \frac{\hbar^2}{\mu_e k e^2} = \frac{\mu_e}{\mu_\mu} a_o = \frac{9.11 \times 10^{-31} \text{ kg}}{1.69 \times 10^{-28} \text{ kg}} (0.0529 \text{ nm}) = 2.85 \times 10^{-4} \text{ nm}$

(b) $E_\mu = \frac{\mu_\mu k^2 e^4}{2 \hbar^2} = \frac{\mu_\mu}{\mu_e} \cdot \frac{\mu_e k^2 e^4}{2 \hbar^2} = \frac{\mu_\mu}{\mu_e} \cdot E_o = \frac{1.69 \times 10^{-28} \text{ kg}}{9.11 \times 10^{-31} \text{ kg}} (13.6 \text{ eV}) = 2520 \text{ eV}$

- (c) The shortest wavelength in the Lyman series is the series limit ($n_i = \infty$, $n_f = 1$). The photon energy is equal in magnitude to the ground state energy $-E_\mu$.

$$\lambda_\infty = \frac{hc}{E_\mu} = \frac{1240 \text{ eV} \cdot \text{nm}}{2520 \text{ eV}} = 0.492 \text{ nm}$$

(The reduced masses have been used in this solution.)