physics 330 HW # 3

(4.6)

a.) scattered fraction $f = \pi b^2 n t$

$$b_{max} = \frac{k q_\alpha Q}{m_\alpha V^2} \cot \frac{\theta}{2} = \frac{k e^2 Z}{E_K} \cot \frac{\theta}{2}$$

for $\theta \geq \frac{\pi}{2}$

$$b_{max} = \frac{k e^2 Z}{E_K}$$

$$f = \pi \left(\frac{k e^2 Z}{E_K} \right)^2 n t$$

$$n = \rho \cdot \frac{1}{M} \cdot N_A = \left(19.3 \ \frac{g}{cm^3}\right)\left(\frac{1 \text{ mol}}{197 \text{ g}}\right)\left(\frac{6.02 \times 10^{23}}{\text{mol}}\right) = 5.9 \times 10^{22} \frac{\text{atoms}}{cm^3}$$

↑ number density

$$n = 5.9 \times 10^{28} \ \frac{\text{atoms}}{m^3} \qquad Z = 79$$

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

$$f = \pi \left(\frac{1.440 \text{ eV} \times 10^{-9} \text{m} \cdot 79}{7.0 \times 10^{6} \text{ eV}} \right)^2 \left(5.9 \times 10^{28} \ m^{-3} \right) \left(2.0 \times 10^{-6} \text{ m} \right)$$

$$f = 9.8 \times 10^{-5}$$

4.b cont.

fraction of particles scattered between 45° and 75°

is $f_{45°} - f_{75°}$

$$f_{45°} - f_{75°} = \pi\left(\frac{Ke^2Z}{E_K}\right)^2 nt \left(\cot\left(\frac{45°}{2}\right) - \cot\left(\frac{75°}{2}\right)\right)$$

↑
Know from part a.)

$$f_{45°} - f_{75°} = 9.8\times10^{-5}\left(\cot\left(\frac{45°}{2}\right) - \cot\left(\frac{75°}{2}\right)\right)$$

$$= 1.1\times10^{-4}$$

c.) Volume per atom

$$\frac{4}{3}\pi r^3 \approx \frac{1}{n}$$

$$r \approx \left(\frac{3}{4\pi n}\right)^{1/3}$$

$$\approx \frac{3}{4\pi \cdot 5.9\times10^{28}\ m^{-3}} = 1.6\times10^{-10}\ m$$

$$= 1.6\ \mathring{A}$$

4.14

$a_0 = \dfrac{\hbar^2}{mke^2}$ $\qquad E_1 = -\dfrac{mk^2 Z^2 e^4}{2\hbar^2}$, $Z=1$ for hydrogen

$\lambda_c = \dfrac{h}{mc}$ $\qquad \alpha = \dfrac{ke^2}{\hbar c}$ ← should be $\hbar$ not h

← should be $\hbar$

$$a_0 = \frac{\hbar c}{\alpha m c^2} = \frac{\hbar c}{mc^2} \cdot \frac{\hbar c}{ke^2} = \frac{\hbar^2}{mke^2}$$ ← OK when using $\hbar$

$$a_0 = \frac{\lambda_c}{2\pi\alpha} = \frac{h}{2\pi mc} \cdot \frac{\hbar c}{ke^2} = \frac{\hbar^2}{mke^2}$$

$\hbar = \dfrac{h}{2\pi}$

$$|E_1| = \frac{1}{2}\alpha^2 mc^2 = \frac{1}{2}\left(\frac{ke^2}{\hbar c}\right)^2 mc^2 = \frac{mk^2e^4}{2\hbar^2}$$

$$a_0 = \frac{\hbar c}{\alpha mc^2} = \frac{197 \text{ eV}\cdot\text{nm}}{\left(\frac{1}{137}\right)(0.511 \times 10^6 \text{ eV})} = .0528 \text{ nm}$$

$$a_0 = \frac{\lambda_c}{2\pi\alpha} = \frac{2.43 \times 10^{-12} \text{ m}}{2\pi/137} = .0530 \text{ nm}$$

$$|E_1| = \frac{1}{2}\left(\frac{1}{137}\right)^2 (0.511 \text{ MeV}) = 13.6 \text{ eV.}$$

4.20

Li, $Z = 3$

$$E = -Z'^2 \left(\frac{E_1}{n^2} \right)$$

ionization energy is energy needed to remove outer electron.

$n_i = 2$

$n_f = \infty$, $E_f = 0$

$$Z' = \left(\frac{-E\, n_i^2}{E_1} \right)^{1/2}$$

$$Z' = \left(\frac{5.39 \text{ eV}}{13.6 \text{ eV}} \right)^{1/2} 2$$

$$Z' = 1.26$$

4.32

a.) tungsten, $Z = 74$

for $n=1$, $Z' = Z-1$

$E_0 = 13.6$ eV

$$E_1 = -\frac{Z^2 E_0}{n^2}$$

$$E_1 = -\frac{(74-1)^2\ 13.6\ \text{eV}}{1^2} = 72.5\ \text{keV}$$

b.)

$$E_1 = -(Z-\sigma)^2 E_0$$

$$Z-\sigma = \left(-\frac{E_1}{E_0}\right)^{1/2}$$

σ must be real

$$\sigma = Z - \left(\frac{E_1}{E_0}\right)^{1/2}$$

Experimental value should have been stated as $E = -69.5$ keV

$$\sigma = Z - \left(\frac{69.5 \times 10^3\ \text{eV}}{13.6\ \text{eV}}\right)^{1/2}$$

$$\sigma = 2.51$$

4.36

Decrease in current when collisions can

raise atom to first excited state.

Electrons need at least $\frac{hc}{\lambda} = \frac{1240 \text{ nm-eV}}{770 \text{ nm}} \approx 1.60 \text{ eV}$

so $V_i = 1.60$ ✓