phys. 225 homework due Nov 13

5.24 eq 5.33: $E_n = -Z^2 E_R/n^2$

is the energy of a single electron about a nucleus of charge Ze.

In the approximation of the problem the K-series is just like the Lyman series except for the Z^2

a) So $E_{Kn} = E_n - E_1 = Z^2 E_R (1 - 1/n^2)$

b) for U, $Z = 92$, $\left(1 - \frac{1}{n^2}\right) = \frac{3}{4}, \frac{8}{9}, \frac{15}{16}$

for $n = 2, 3, 4$

and $E_\gamma = hf = hc/\lambda \rightarrow \lambda = hc/E_\gamma$

So $\lambda_{K\alpha} = \frac{1240}{(92^2)(13.6)} \cdot \frac{4}{3} = 0.0108 \cdot \frac{4}{3} = 0.0144$ nm

$\lambda_{K\beta} = \frac{3}{4} \cdot \frac{9}{8} \lambda_{K\alpha} = 0.0108 \cdot \frac{9}{8} = 0.0121$ nm

$\lambda_{K\gamma} = \frac{3}{4} \cdot \frac{16}{15} \lambda_{K\alpha} = 0.0108 \cdot \frac{16}{15} = 0.0115$ nm

5.25 $R_{n=1} = a_B/Z = \frac{0.05 \text{ nm}}{82} = 0.6$ pm or $.6 \times 10^{-12}$ m

Which is 100x bigger than the lead nucleus with $R = 7 \times 10^{-15}$ m

5.26 Silver, $Z = 47$

$R_{\mu, n=1} = \frac{a_B}{Z} \frac{m_e}{m_\mu} = \frac{0.05}{47} \frac{1}{207} = 5 \times 10^{-6}$ nm $= 5 \times 10^{-15}$ m

since $a_B \propto 1/m_e$

5.26 - continued

a.) the μ is way inside all the electrons, so it is OK to ignore them. It may be inside the nucleus too...

b.) $E_{\mu Z n} = \frac{m_\mu}{m_e} \frac{E_R}{n^2} Z^2$ since $E_R \propto m_e$

so $E_\gamma = \frac{m_\mu}{m_e} E_R Z^2 \left(1 - \frac{1}{2^2}\right)$

$= (207)(13.6)(47)^2(3/4) = 4.66\ \text{MeV}$

$\lambda = hc/E = \frac{1240\ \text{MeV}\cdot\text{fm}}{4.66\ \text{MeV}} = 266\ \text{fm}$

5.27 For an atom initially stationary,

a.) final $P = \Delta P$ of electron.

max ΔP of electron occurs when it bounces backwards. The magnitude of its $\vec{p}$ is hardly changed, since the nucleus takes very little K away.

$\Delta P = 2P_0 = 2\sqrt{2 m_e K_0} = P_{atom}$

for atom, $K = \frac{P_{atom}^2}{2M_{atom}} = \frac{4(2 m_e K_0)}{2 M_{atom}}$

$= 4 \frac{m_e}{M_A} K_0$

5.27 - continued

b.) $K_0 = 3eV$, $m_e = 0.511\ MeV/c^2$

$M_{Hg} = A_{Hg}(931.5)\ MeV/c^2$

$A_{Hg} = 200.6$ (averaged over all the isotopes.)

The isotopes have $A = 198, 199, 200, 201$ and 204

200 is a nice round number.

$$\max K = 4\frac{0.5}{(200)(932)}\,3 = 3\times10^{-5}\,eV \text{ for atom}$$

$$\text{units: } \frac{MeV\cdot eV}{MeV} = eV$$

6.8 $p = h/\lambda \Rightarrow pc = hc/\lambda$

if $\lambda = 0.05\,nm$ $\quad pc = \frac{1240}{0.05} = 25\ keV$

for photons, $E = pc$ so we need 25 keV x-rays.

for neutrons, $K = p^2/2m$ (since $p \ll mc$)

$$= \frac{p^2c^2}{2mc^2} = \frac{25^2}{(2)(938\times10^3)} = 0.33\,eV$$

for electrons $K = p^2c^2/2mc^2$ is still ok

$$= \frac{25^2}{(2)(511)} = 0.61\ keV$$

6.11 $E^2 = (pc)^2 + (mc^2)^2$, $E = mc^2 + K$

	K	E	pc	$\lambda = hc/pc$
electron $mc^2 = 511 \times 10^3 eV$	10^3 eV	512 keV	32 keV	39 pm
	10^6 eV	1511 keV	1422 keV	0.87 pm
	10^9 eV	1.0005 GeV	1.0005 GeV	1.24 fm
photon $m = 0$	10^3 eV	10^3 eV	10^3 eV	1.24 nm
	10^6 eV	10^6 eV	10^6 eV	1.24 pm
	10^9 eV	10^9 eV	10^9 eV	1.24 fm

recall nm $= 10^{-9}$ m

pm $= 10^{-12}$ m

fm $= 10^{-15}$ m