5.14  eq 5.33: \[ E_n = -Z^2 \frac{e^2}{4\pi \epsilon_0 r} \]

15. The energy of a single electron about a nucleus of charge \( Z \). 

In the approximate case the proton is just like the hydrogen atom except for the \( Z \).

a) \( L = L_n = L_n^2 = Z^2 \frac{\hbar^2}{2} (1 - \frac{1}{r}) \)

b) For \( Z = 92, (1 - \frac{1}{r}) \approx \frac{3}{4}, \frac{8}{9}, \frac{15}{16} \)

For \( n = 2, \frac{3}{4} \)

\[ \hbar^2 = \frac{\hbar^2}{2} \rightarrow \hbar = \hbar \sqrt{2} \]

So \( \lambda k^2 = \frac{12.40}{92 \lambda (1.6)} \frac{4}{3} = 0.108 \lambda = 0.0147 \text{ nm} \)

\[ \lambda k = \frac{3}{4}, \frac{9}{8} \lambda k = 0.0108 \frac{3}{8} = 0.0122 \text{ nm} \]

\[ \lambda k = \frac{3}{4}, \frac{4}{15} \lambda k = 0.0108 \frac{3}{15} = 0.0116 \text{ nm} \]

5.25 \[ R_{n1} = \frac{d}{\lambda} = 0.05 \text{ nm} = 0.6 \text{ pm} \]

Which is \( 10^2 \times \) bigger than the lead nucleus with \( r = 7 \times 10^{-8} \text{ m} \)

5.26 Silver, \( Z = 47 \)

\[ R_{m1} = \frac{A \frac{m}{2}}{Z^{3/2}} = 0.05 \frac{1}{47} \text{ nm} = 5 \times 10^{-10} \text{ m} \]

Since \( a \geq R_m \),
5.26 - continued

a) The \( m_1 \) is very inside all the electrons, so it is ok to ignore them. It may be inside the nucleus too.

b) \( E_{\text{kin}} = \frac{m_1 E_R^2}{m_2} \) since \( E_1 \propto m_1 \)

\[
E_1 = \frac{m_1 E_R^2}{m_2} \left ( 1 - \frac{1}{2} \right )
\]

\[
= \frac{(20)(3.4 \times 10^7)}{(5)} \left ( \frac{3}{4} \right ) = 4.66 \text{ MeV}
\]

\[
\gamma = \frac{E_1}{E_2} = \frac{4.66 \text{ MeV}}{\frac{4.66 \text{ MeV}}{4.66 \text{ MeV}}}
\]

5.27 For an atom initially stationary,

a) Final \( P = AP \) of electron.

\( \Delta P \) of electron occurs when it bounces backwards. The magnitude of its \( P \) is hardly changed, since the nucleus is very little \( K \) away.

\[
\Delta P = 2P = 2\sqrt{2ZeK} = P_{\text{max}}
\]

For atom, \( K = \frac{P_{\text{max}}}{2m_1 \text{kin}} = \frac{4(3.4 \times 10^7)}{2m_1 \text{kin}}
\]

\[
= 4 \frac{m_1 \text{MeV}}{m_1 \text{MeV}} K
\]
6.27 - 

6) \( K = 3 \text{eV}, \quad M_{e} = 0.58 \text{ MeV/c}^{2} \)

\[ M_{h} = \lambda_{h} (0.915) \text{ MeV/c}^{2} \]

\[ A_{19} = 200.65 \quad \text{(averaged over all the isotopes)} \]

The isotopes have \( A = 198, 199, 200, 201\) and 204, 208 is a nice round number.

Max \( K = \frac{4}{(2\pi)(932)} \times 3 = 3 \times 10^{-5} \text{eV for } a \text{ atom} \)

Units: \( \text{MeV} \cdot \text{eV} = 0 \text{eV} \)

6.8 p = h/\lambda \Rightarrow p = 6e/\lambda

if \( h = 0.05 \text{nm}, \quad pc = \frac{1240}{0.05} = 25 \text{ BeV} \)

for photons, \( E = p^2 \Rightarrow \text{we need } 25 \text{ BeV x-rays} \)

for neutrons \( K = \frac{p^2}{2m} \quad (\text{Since } p < m) \)

\[ = \frac{p^2}{2m^2} = \frac{25^2}{(2)(938 \times 10^3)} = 0.33 \text{ eV} \]

for electrons \( K = \frac{p^2}{2me^2} \quad \text{is } 3 \text{ MeV} \)

\[ = \frac{25^2}{(2)(511)} = 0.61 \text{ MeV} \]
\[ E^2 = (pc)^2 + (mc^2)^2, \quad E = mc^2 + \pi \]

<table>
<thead>
<tr>
<th></th>
<th>K</th>
<th>E</th>
<th>pc</th>
<th>( \pi = \frac{\lambda}{2c} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron</td>
<td>10^3 eV</td>
<td>2.2 MeV</td>
<td>3.2 MeV</td>
<td>39 pm</td>
</tr>
<tr>
<td></td>
<td>10^6 eV</td>
<td>1.8 MeV</td>
<td>1.1 MeV</td>
<td>0.87 fm</td>
</tr>
<tr>
<td></td>
<td>10^9 eV</td>
<td>1.008 GeV</td>
<td>1.008 GeV</td>
<td>1.24 fm</td>
</tr>
</tbody>
</table>

| photon | 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 pm                        |

\( m = 0 \)

\( \sqrt{c} \text{call} \quad \lambda = 10^{10} \text{m} \)

\( \lambda = 10^{12} \text{m} \)

\( f = 10^{15} \text{Hz} \)