3rd ed

4-12

Lyman Series in Hydrogen Spectrum

$n_f = 1$

$n_i = 2, 3, 4, 5$ etc

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = 1.0973732 \times 10^7 \text{ m}^{-1}\left(\frac{1}{1^2} - \frac{1}{n_i^2}\right)$$

n_i	λ_i (m)	λ_i (nm)
2	1.215×10^{-7}	121.5
3	1.025×10^{-7}	102.5
4	9.720×10^{-8}	97.2

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~~3-14~~ $r_n = \frac{n^2 a_0}{Z}$, $a_0 = 0.529$ Å

For Hydrogen, $Z = 1$.

a. $r_1 = a_0 = 0.529$ Å
$r_2 = 4a_0 = 2.116$ Å
$r_3 = 9a_0 = 4.761$ Å

b. Assuming uniform circular motion, as the Bohr model does, and quantized angular momentum

$$m_e v_n r_n = n\hbar, \quad \text{solve for } v_n$$

$$v_1 = \frac{\hbar}{m_e a_0} = \frac{6.582\times10^{-16}\ \text{eV sec}}{0.511\times10^{6}\ \frac{\text{eV}}{c^2}\cdot .529\times10^{-10}\ \text{m}}$$

$$v_1 = 0.0073c = 2.19\times10^{6}\ \text{m/sec}$$

$$v_2 = \frac{2\hbar}{m_e r_2} = \frac{2}{4}\frac{\hbar}{m_e a_0} = \frac{1}{2}v_1 = 1.10\times10^{6}\ \text{m/sec}$$

$$v_3 = \frac{3\hbar}{m_e r_3} = \frac{3}{9}\frac{\hbar}{m_e a_0} = \frac{1}{3}v_1 = 0.73\times10^{6}\ \text{m/sec}$$

c. Since these speeds are $\sim \frac{1}{100}c$, one wouldn't apply a relativistic correction.

4-16

~~3.11~~ For Li^{++}, $Z = 3$, so from Eqn 3.36 the energy levels are

$$E_n = \frac{-13.6\, Z^2}{n^2}\, eV = \frac{-122.4}{n^2}\, eV$$

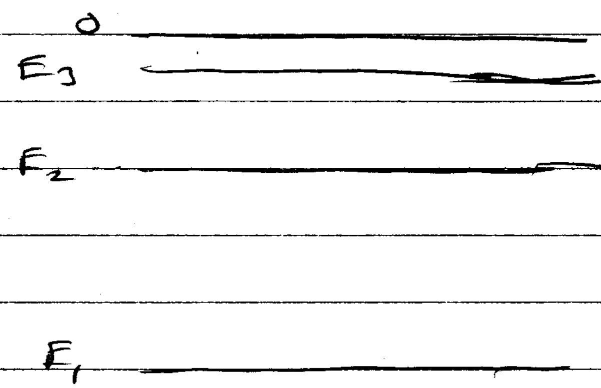
Plug in $n = 1, 2, 3, \ldots$

$E_1 = -122.4\, eV$

$E_2 = -30.6\, eV$

$E_3 = -13.6\, eV$

$\vdots$



4.17 in 3rd ed

3.17 The radius of the first ($n=1$) Bohr orbit for hydrogenic atoms is

$$r_n = \frac{n^2\hbar^2}{Zmke^2} = \frac{n^2}{Z}\frac{\hbar^2}{mke^2}, \quad n=1$$

$$r_1 = \frac{5.30 \times 10^{-11}\ \text{m}}{Z}$$

For He^+, $Z=2 \Rightarrow r_1 = 2.65 \times 10^{-11}$ m

For Li^{2+}, $Z=3 \Rightarrow r_1 = 1.77 \times 10^{-11}$ m

For Be^{3+}, $Z=3 \Rightarrow r_1 = 1.32 \times 10^{-11}$ m

4.18 3rd ed

~~3.18~~ The energy levels for the Bohr Hydrogen atom are

$$E_n = \frac{-13.6\,eV}{n^2}$$

a) The change in energy in a transition from the $n=1$ to $n=3$ levels is

$$\Delta E = E_1 - E_3$$

$$= -13.6\,eV\left(1 - \frac{1}{9}\right)$$

$$= 12.1\,eV$$

b) The return to the ground state can be done by 2 routes:

$n=3$ to $n=1$ or

$n=3$ to $n=2$ to $n=1$

In the first case, the emitted photon is 12.1 eV.

In the second case, 2 photons are emitted, of energies 1.89 eV and 10.2 eV.

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4-20

$$\Delta E = -13.6\,eV\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

a) $\Delta E = -13.6\,eV\left(\frac{1}{25} - \frac{1}{16}\right) = 0.306\,eV$

$n_f = 5 \quad n_i = 4$

b) $\Delta E = -13.6\,eV\left(\frac{1}{36} - \frac{1}{25}\right) = 0.166\,eV$

$n_f = 6 \quad n_i = 5$

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These 2 are kind of alike..

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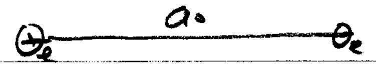
~~3-22~~

$n=1, \quad r_1 = a_0$



Potential energy $\quad U = -\dfrac{ke^2}{a_0} = \dfrac{8.988\times10^{9}\,\frac{Nm^2}{C^2}\,(1.602\times10^{-19}C)^2}{.5292\times10^{-10}m}$

$U = -4.36\times10^{-18}J = -27.21\,eV$

Kinetic energy $\quad K = E - U$

$= -13.6eV - (-27.2eV)$

$= 13.6\,eV = 2.18\times10^{-18}J.$

4-23
~~3-23~~ $\quad n=1$

a) $r_n = \dfrac{a_0}{1} = a_0$

b) $p = m_e v = m_e \dfrac{\hbar}{m_e r_1} = \dfrac{\hbar}{a_0} = 1.78\times10^{-24}\ \dfrac{kg\,m}{sec}$

c) $L = m_e v r = \hbar$

d) $K = \frac{1}{2}m_e v^2 = \frac{1}{2}m_e\left(\dfrac{\hbar}{m_e a_0}\right)^2 = \dfrac{1}{2m_e}\dfrac{\hbar^2}{a_0^2} = 2.18\times10^{-18}J = 13.6eV$

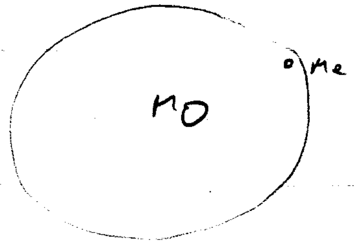
e) $U = -\dfrac{ke^2}{a_0} = -27.2eV$

f) $E_1 = K+U = -13.6eV \left(= -\dfrac{ke^2}{2a_0}\right)$

$= -2.18\times10^{-18}J.$

24-32

~~3-32~~ reduced mass $\mu = \frac{m_e M}{m_e + M}$; $m_e = 9.109 \times 10^{-31}$ kg



$$E_n = -\frac{\mu k e^2}{2 m_e a_0} \frac{1}{n^2}$$

$$R = 1.097 \times 10^7 \text{ m}^{-1}$$

$$\frac{1}{\lambda} = \frac{\mu}{m_e} R \left| \frac{1}{n_f^2} - \frac{1}{n_i^2} \right|$$

$n_f = 3$ $n_i = 2$ $\left| \frac{1}{9} - \frac{1}{4} \right| = .139$

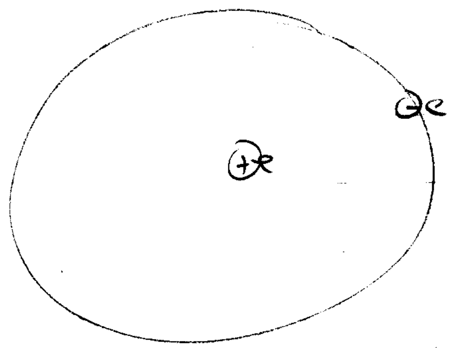
$$\frac{1}{\lambda} = \frac{\mu}{m_e} R \, (.139)$$

	M (kg)	μ (kg)	$\frac{1}{\lambda}$ (m^{-1})	λ (m)
a)	1.67×10^{-27}	9.104×10^{-31}	1.524×10^{6}	6.562×10^{-7}
b)	3.34×10^{-27}	9.106×10^{-31}	1.5244×10^{6}	6.560×10^{-7}
c)	5.01×10^{-27}	9.107×10^{-31}	1.525×10^{6}	6.559×10^{-7}

(I just used $M = 2(m_p) + 3(m_p)$.)

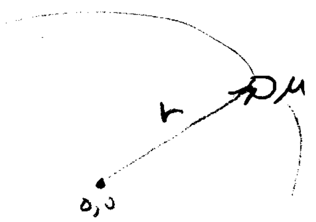
4-35

~~3-35~~



$$m_+ = m_e = 9.109 \times 10^{-31}\,\text{kg} = 0.511\,\frac{\text{MeV}}{c^2}$$

The reduced mass is $\mu = \dfrac{m_+ m_e}{m_+ + m_e} = \frac{1}{2} m_e = 4.55 \times 10^{-31}\,\text{kg}$



[See Fig P3.32]

In the formulae for the Bohr model, we just replace m_e with μ everywhere. Also, $Z=1$.

$$r_n = \frac{n^2 \hbar^2}{\mu k e^2} = n^2 \frac{2\hbar^2}{m_e k e^2} = 2n^2 a_0$$

The energy levels are

$$E_n = -\frac{ke^2}{2\left(\frac{\hbar^2}{\mu k e^2}\right)} \frac{1}{n^2} = -\frac{\mu k^2 e^4}{2\hbar^2} \frac{1}{n^2}$$

$$E_n = -\frac{1}{2} m_e \frac{k^2 e^4}{2\hbar^2} \frac{1}{n^2} = -\frac{ke^2}{4a_0} \frac{1}{n^2}$$