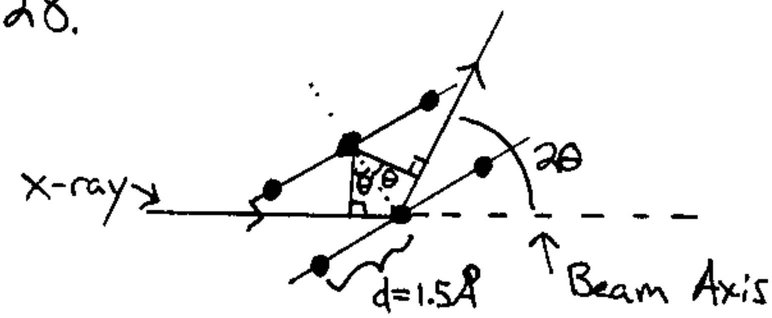
Ch. 27

25. $2d\sin\theta = m\lambda$ $\quad m=1$, $\theta = 25°$, $\lambda = .090 \times 10^{-9}$ m

$$d = \frac{m\lambda}{2\sin\theta} = \frac{(1)(.090\times10^{-9})}{2(\sin 25°)} = 1.065\times10^{-10}\text{ m}$$

or 1.065 Å

28.



See fig. 27.8 c) on pg. 1083

30° off beam axis $\Rightarrow 2\theta = 30°$

$\theta = 15°$

1st order peak $\Rightarrow m=1$

$\therefore \lambda = 2d\sin\theta$

$= 2(1.5\text{Å})\sin 15° = .78$ Å

36. $2d\sin\theta = m\lambda$ $\quad d = .500$ Å $\quad \theta = 30°$

$$\lambda = \frac{2d\sin\theta}{m}$$

$$= \frac{2(.500\text{Å})\sin 30°}{m}$$

$$= \frac{2(.500\text{Å})(\frac{1}{2})}{m} \Rightarrow \lambda = \frac{.500\text{Å}}{m} \quad m = 1,2,3,\ldots$$

Ch. 27

38. As the α-particle moves closer to the gold nucleus, the kinetic energy of the α-particle is being converted into potential energy between it and the nucleus and consequently slowing down. When all its initial kinetic energy becomes stored as potential energy, the α-particle will not move any closer to the nucleus.

$\therefore$ closest when K.E. = P.E.

K.E $= 8.00\times10^{-13}$ J

$$P.E. = \frac{k_o(Ze)(2e)}{r} \qquad Z_{gold} = 79$$

$$\Rightarrow 8.00\times10^{-13}\,J = \frac{k_o(79e)(2e)}{r} \qquad k_o = \frac{1}{4\pi\epsilon_o}$$

$\epsilon_o = 8.85\times10^{-12}$

$$r = \left(\frac{1}{4\pi\epsilon_o}\right)\frac{158e^2}{8.00\times10^{-13}}$$

$$= \frac{158(1.6\times10^{-19})^2}{4\pi(8.85\times10^{-12})(8.00\times10^{-13})}$$

$$= 4.55\times10^{-14}\,m$$

or 45.5 fm

Ch. 27

43. $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

Series limit as $n \to \infty$

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \cancel{\frac{1}{\infty}}^{\,0}\right]$$

$$\frac{1}{\lambda} = \frac{R}{4} \Rightarrow \lambda = \frac{4}{R} = \frac{4}{1.097\times10^{7}} = 3.646\times10^{-7}\,\text{m}$$

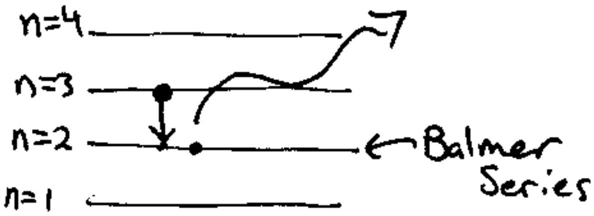
or 364.6 nm

47. $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

Longer wavelength = Lower energy

Since $n = 3, 4, 5 \ldots$

Lowest energy is from the $n=3$ to $n=2$ transition



$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{3^2}\right]$$

$$= R\left[\frac{9-4}{36}\right]$$

$$= 1.097\times10^{7}\left(\frac{5}{36}\right)$$

$$\Rightarrow \lambda = \frac{1}{1.097\times10^{7}}\left(\frac{36}{5}\right) = 6.563\times10^{-7}\,\text{m} \text{ or } 656.3\,\text{nm}$$

51. $\lambda_{min} = 390\,\text{nm}$

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$$

$$\frac{1}{R\lambda_{min}} = \frac{1}{4} - \frac{1}{n^2}$$

$$\frac{1}{n^2} = \frac{1}{4} - \frac{1}{R\lambda_{min}}$$

51. (cont.)

$$\frac{1}{n^2} = \frac{R\lambda_{min} - 4}{4R\lambda_{min}}$$

$$n^2 = \frac{4R\lambda_{min}}{R\lambda_{min} - 4}$$

$$n = \sqrt{\frac{4R\lambda_{min}}{R\lambda_{min} - 4}} = \sqrt{\frac{4(1.097\times10^{7})(390\times10^{-9})}{R\lambda_{min} - 4}}$$

$$= \sqrt{\frac{17.1132}{4.2783 - 4}}$$

$$= \sqrt{61.49} = 7.8$$

highest integer = 7

$\therefore \lambda_{min}$ @ $n = 7$

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{4} - \frac{1}{7^2}\right] = R\left(\frac{49-4}{196}\right)$$

$$\Rightarrow \lambda_{min} = \frac{1}{R}\left(\frac{196}{45}\right)$$

$$= 3.97\times10^{7}\,m$$

or 397 nm

Ch. 28

1. $P = \epsilon \sigma A T^4$ $\sigma = 5.67 \times 10^{-8}$ $\epsilon = .97$

$I = \frac{P}{A} = \epsilon \sigma T^4$ $T_{body} = 306K$

$T_{room} = 293K$

The skin is emitting radiation according to its temp. but it is also absorbing radiation from the room according to the room's temp.

$\therefore$ Net power radiated off the skin

= Radiation emitted by body @ 306K

− Radiation absorbed by body @ 293K

$$I = \frac{P}{A} = (.97)(5.67\times10^{-8})(306)^4 - (.97)(5.67\times10^{-8})(293)^4$$

$$= (.97)(5.67\times10^{-8})(306^4 - 293^4)$$

$$= 77 \frac{W}{m^2}$$

$P = IA = (77 \frac{W}{m^2})(1.4 m^2) = 108W$ Total energy lost per second

Ch. 28

3. $T = 306\,K$

$$\lambda_{peak} T = .002898$$

$$\lambda_p = \frac{.002898}{306} = 9.47 \times 10^{-6} m \quad \text{or } 9.47\,\mu m$$

7. $T = 1000\,K$

$$\lambda_p = \frac{.002898}{T} = \frac{.002898}{1000} = 2.898 \times 10^{-6} m \quad \text{or } 2.898\,\mu m$$

8. Total Energy = Power x time $\quad t = 5\text{ hrs}$

$P = \sigma A T^4 \quad$ Energy $= Pt = 500J \ @ \ T_0 = 293K$

$\qquad\qquad\qquad = X \quad @ \ T_1 = 1273K$

$$Pt = \sigma A T_0^4 t = 500\,J \implies t = \frac{500\,J}{\sigma A T_0^4}$$

$$\sigma A T_1^4 t = X \qquad t = \frac{X}{\sigma A T_1^4}$$

$$\therefore \frac{500\,J}{\sigma A T_0^4} = \frac{X}{\sigma A T_1^4}$$

$$\rightarrow \left(\frac{T_1^4}{T_0^4}\right)(500\,J) = X$$

$$\left(\frac{1273^4}{293^4}\right)(500\,J) = 178{,}000\,J$$

Ch. 28

9. Total Energy $= Pt = 180\,J$

$$t = 8\,hr\left(\frac{3600\,sec}{1\,hr}\right) = 28{,}800\,sec$$

$$P = \sigma A T^4 \qquad T = 293\,K$$

$$\Longrightarrow \sigma A T^4 t = 180\,J$$

$$A = \frac{180}{\sigma T^4 t} = \frac{180}{(5.67\times10^{-8})(293)^4(28{,}800)}$$

$$= 1.5\times10^{-5}\,m^2$$

19. Energy per photon $\Rightarrow E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{550\times10^{-9}}$

$$= 3.614\times10^{-19}\,J/photon$$

Total photon Power $=$ (energy per photon)(# of $\frac{photons}{sec}$)

$$= \left(3.614\times10^{-19}\,\frac{J}{photon}\right)\left(2\times10^{13}\,\frac{photons}{sec}\right)$$

$$P = 7.228\times10^{-6}\,\frac{J}{s}\text{ or } W$$

$$A = 1\,cm^2\left(\frac{1\,m}{100\,cm}\right)^2 = 1\times10^{-4}\,m^2$$

$$I = \frac{P}{A} = \frac{7.228\times10^{-6}\,W}{1\times10^{-4}\,m^2} = .0723\,\frac{W}{m^2}$$

Ch. 28

21. $E_{in} = E_{out}$

$$E_{in} = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{650\times10^{-9}} = 3.058\times10^{-19}\,J$$

$$E_{out} = \underbrace{\cancel{K.E.}_{electron}}_{0} + \phi \text{ (stopping potential)}$$

0 (problem states that K.E. is negligible)

$E_{out} = \phi$

$\Longrightarrow \quad 3.058\times10^{-19}\,J = \phi$

All this energy got absorbed by the metal and converted into mechanical energy and heat.

$E_\phi = hf = 3.058\times10^{-19}\,J$

$$f = \frac{3.058\times10^{-19}}{6.626\times10^{-34}} = 4.62\times10^{14}\,Hz$$

Threshold frequency because it is the highest frequency, and highest energy, photon that the metal can completely absorb before it has to get rid of energy by spitting out an electron.

Ch. 28

25. The electron's kinetic energy gets converted to potential energy as it moves towards the charged plate. As the potential is increased the electrons arrive at slower and slower velocities until the potential is increased to a point where electrons don't arrive at all. At that instant, all the kinetic energy of the electron gets stored as electrostatic potential energy with no energy to continue motion towards the plate. Since the electrons don't jump the gap the current goes to zero, as in this problem.

$\therefore$ all K.E. $\rightarrow$ P.E. $\Rightarrow$ K.E. = P.E.

Electrostatic potential energy for a charge = qV ← Voltage or potential at that point in space

$q = e^-$

$V = 1.25V$

$$K.E. = \frac{1}{2} m_e v^2$$

$$\Rightarrow \frac{1}{2} m_e v^2 = eV$$

$$v = \sqrt{\frac{2eV}{m_e}} = \sqrt{\frac{2(1.6\times10^{-19})(1.25)}{9.11\times10^{-31}}}$$

$$= 6.63\times10^{5}\frac{m}{s}$$

Ch. 28

28. First we need to solve for the stopping potential, ϕ, which will give us the minimum energy, and thus frequency, required to kick out an electron.

$$E_{in} = \frac{hc}{\lambda} \quad \lambda = 250\times10^{-9}\,m$$

$$= \frac{(6.626\times10^{-34})(3\times10^{8})}{250\times10^{-9}} = 7.95\times10^{-19}\,J$$

$$E_{out} = K.E. + \phi \qquad K.E. = 1\times10^{-19}\,J$$

$$= \tfrac{1}{2}mv^2 + \phi$$

$E_{in} = E_{out}$

$$7.95\times10^{-19}\,J = 1\times10^{-19}\,J + \phi$$

$$\phi = (7.95 - 1)\times10^{-19}\,J$$

$$= 6.95\times10^{-19}\,J$$

Lowest frequency photon is the lowest energy photon, and the lowest E_{in} occurs when $K.E. = 0$

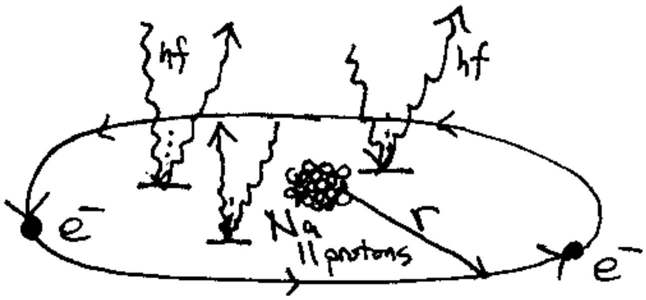
$$\rightarrow E_{in} = \phi$$

$$hf = 6.95\times10^{-19}\,J$$

$$f = \frac{6.95\times10^{-19}\,J}{6.626\times10^{-34}\,J\cdot s} = 1.05\times10^{15}\,Hz$$

Ch.28

31.

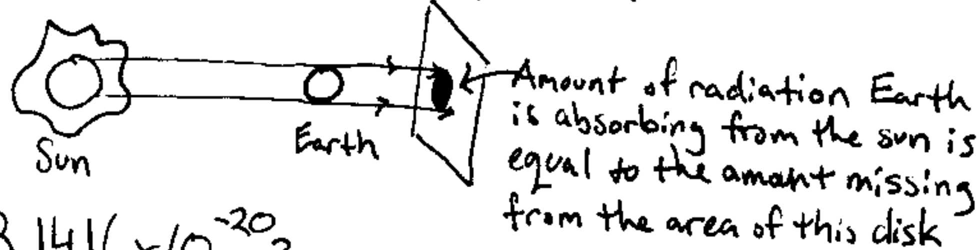


Na: $\phi_{Na} = 2.28\,eV$ (pg. 1113)

$Z_{Na} = 11$

$r = .10\,nm$

The effective area the intensity is distributed over is $A = \pi r^2$. Just as the sun's intensity incident on Earth is computed with the area of the shadow the Earth makes against a plane, so is it here; even though the area of the hemisphere is $\frac{1}{2}A_{sphere} = 2\pi r^2$ it only absorbs the same amount of radiation as a disk would.



$$A = \pi(.1\times10^{-9})^2 = 3.1416\times10^{-20}\,m^2$$

$$I_{laser} = 10\,\frac{W}{m^2}$$

The electron needs to absorb at least as much energy as the stopping potential before it will escape the metal.

$$P_{e^-} = IA = \left(10\,\frac{W}{m^2}\right)\left(3.1416\times10^{-20}\,m^2\right) = 3.1416\times10^{-19}\,W$$

$$3.1416\times10^{-19}\,\frac{J}{s}\left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right) = 1.96\,\frac{eV}{sec}$$

31 (cont.)

$$E_{\substack{Total\\absorbed}} = Pt = \left(1.96\ \frac{eV}{s}\right)t$$

$\phi = 2.28\,eV$ $\quad$ $Pt = \phi$

$$t = \frac{\phi}{P} = \frac{2.28\,eV}{1.96\ \frac{eV}{s}} = 1.16\,sec$$

However, if $I = 1\ \frac{\mu W}{m^2}$

then
$$t = \frac{\phi}{P} = \frac{\phi}{IA} = \frac{2.28\,eV}{\left(1\times10^{-6}\frac{W}{m^2}\right)\left(\frac{1\,eV}{1.6\times10^{-19}\,W}\right)\left(3.1416\times10^{-20}\,m^2\right)}$$

$$= 1.16\times10^{7}\,sec$$

$$= 134\ days$$

$\therefore$ The classical electrodynamic interpretation of this problem is obviously incorrect.

Ch. 28

32. $E = hf_{max} = \frac{hc}{\lambda_{shortest}} = eV \qquad V = 30\times10^{3}V$

$$\Rightarrow \lambda = \frac{hc}{eV} = \frac{(6.626\times10^{-34}J\cdot s)(3\times10^{8}\frac{m}{s})}{(1.6\times10^{-19}c)(30\times10^{3}J/c)}$$

$$= \frac{1.988\times10^{-25}J\cdot m}{4.8\times10^{-15}J}$$

$$= 4.14\times10^{-11}m \quad \text{or } 0.414\ \text{Å}$$

44. $E_n = -\frac{13.6eV}{n^2}$ 1st excited state $\Rightarrow n=2$

$n=1$ for ground state

$$E_2 = -\frac{13.6eV}{2^2} = \underline{-3.40eV}$$

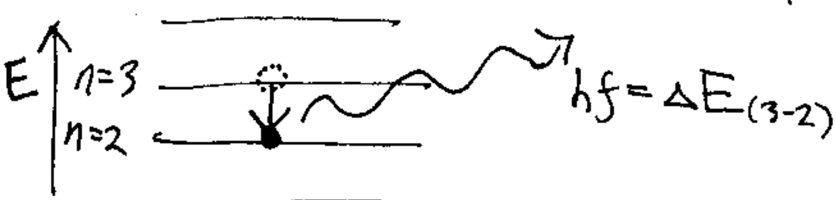
$$-3.40eV\left(\frac{1.6\times10^{-19}J}{1eV}\right) = \underline{-5.44\times10^{-19}J}$$

45. 2nd excited state $\Rightarrow n=3$

$$E_3 = -\frac{13.6eV}{3^2} = \underline{-1.51eV}$$

46. $E_3 - E_2 = E_{photon}$

$$-1.51eV - (-3.40eV) = 1.89eV\left(\frac{1.6\times10^{-19}J}{1eV}\right) = \underline{3.024\times10^{-19}J}$$



Ch. 28

47. The difference in energy between the energy levels goes into making the photon.

$$E_{photon} = \Delta E_{(3-2)} = E_3 - E_2 = 1.89\,eV$$

$$\therefore E_{photon} = hf = \frac{hc}{\lambda} = 1.89\,eV \Rightarrow f = \frac{1.89\,eV}{4.136\times10^{-15}\,eV\cdot sec} = 4.57\times10^{14}\,Hz$$

$$\lambda = \frac{hc}{1.89} = \frac{(4.136\times10^{-15}\,eV\cdot s)(3\times10^{8}\,\frac{m}{s})}{1.89\,eV}$$

$$= 6.57\times10^{-7}\,m$$

or 657 nm

58. for K_α lines $f = \left(\frac{3cR}{4}\right)(Z-1)^2$

or $\frac{1}{\lambda} = R(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$ $\lambda = .0759\,nm$

$$= R(Z-1)^2\left(\frac{3}{4}\right)$$

$$\frac{4}{3R\lambda} = (Z-1)^2$$

$$\sqrt{\frac{4}{3R\lambda}} = Z-1$$

$$\Rightarrow Z = \sqrt{\frac{4}{3R\lambda}} + 1 = \sqrt{\frac{4}{3(1.097\times10^{7})(.0759\times10^{-9})}} + 1$$

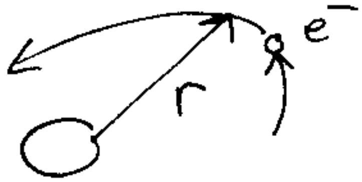
$$= 40.02 + 1$$

$$= 41$$

Z = 41 protons for <u>Niobium</u>

Ch. 28

59.



Angular Momentum: $L_n = M_e v_n r_n = n\hbar$ $\quad \hbar = \frac{h}{2\pi} = 1.05\times10^{-34}\,J\cdot s$

Ground State $\Rightarrow n=1$

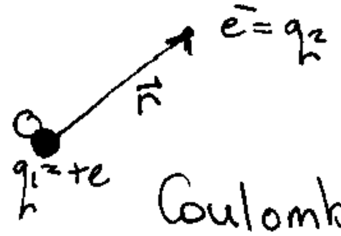
$\therefore r_n = n^2 r_1 = 1^2 r_1 = r_1 = .0529\times10^{-9}\,m$ (Bohr Radius)

$\Rightarrow M_e v r_1 = (1)\hbar$

$$v = \frac{\hbar}{M_e r_1} = \frac{1.05\times10^{-34}\,J\cdot s}{(9.109\times10^{-31}\,kg)(.0529\times10^{-9}\,m)}$$

$$= 2.18\times10^{6}\,\frac{m}{s}$$

60.



Ground State: $r = r_1 = .0529\times10^{-9}\,m$

Coulomb's Law: $\vec{F} = \frac{k_0 q_1 q_2}{r^2}\hat{r}$

q_1 = hydrogen nucleus (1 proton) = $+e$

q_2 = electron = $-e$

$k_0 = \frac{1}{4\pi\epsilon_0} = \frac{1}{4\pi(8.85\times10^{-12})} = 8.99\times10^{9}$

$$\vec{F} = \frac{k_0(+e)(-e)}{r_1^2}\hat{r} = \frac{-(8.99\times10^{9})(1.6\times10^{-19})^2}{(.0529\times10^{-9})^2}\hat{r} = \frac{-2.3\times10^{-28}}{2.798\times10^{-21}}\hat{r}$$

$$= -8.22\times10^{-8}\,\hat{r}\,N \quad \text{or} \quad 8.22\times10^{-8}(-\hat{r})\,N$$

attractive force

Ch. 28

66. Atomic # for Helium = $Z_{He} = 2$

$n = 4$ (3^{rd} excited state)

General E_n equation for Elements other than Hydrogen:

$$\rightarrow E_n = -\frac{2\pi^2 k_o^2 e^4 m_e}{h^2} \frac{Z^2}{n^2}$$

$$_{He}E_4 = \frac{-2\pi^2(8.99\times10^9)^2(1.6\times10^{-19})^4(9.109\times10^{-31})}{(6.626\times10^{-34})^2} \cdot \frac{2^2}{4^2}$$

$$= \frac{-9.524\times10^{-85}}{4.39\times10^{-67}}\left(\frac{1}{4}\right)$$

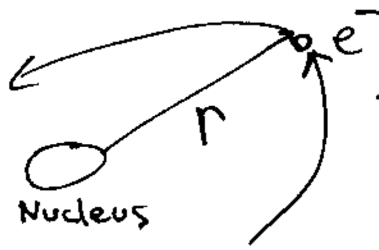
$$= -5.42\times10^{-19}\,J\left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right) = \underline{-3.39\,eV} \quad E_{4\,helium}$$

$$E_{2\,Hydrogen} = \frac{-13.6\,eV}{n^2} = \frac{13.6\,eV}{4} = \underline{-3.4\,eV}$$

1^{st} exc. state

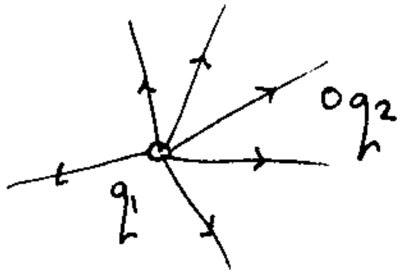
$n=2$

Apparently Helium's 3^{rd} excited state has almost the same exact energy as Hydrogen's 1^{st} excited state. Not that ~~that~~ any of it is that exciting at all...

67. 

The orbitting electron has kinetic and potential energy.

Potential Energy between 2 charges is $\frac{k_o q_1 q_2}{r}$



Potential or "voltage" from q_1: $V(r) = \frac{k_o q_1}{r}$

Potential Energy of $q_2 = \left(\begin{array}{c}\text{Potential at} \\ q_2\text{'s point in space}\end{array}\right)(\text{Charge of } q_2)$

$= V(r)\, q_2$

$P.E. = \frac{k_o q_1 q_2}{r}$

By Symmetry, the P.E. of q_1 = P.E. of $q_2 = \frac{k_o q_1 q_2}{r}$

let q_1 be the nucleus

$q_1 = (\# \text{ of protons})(\text{charge of proton})$

$= (\underset{\text{Atomic \#}}{Z})(\underset{= +e}{1.6 \times 10^{-19} C})$

let q_2 be the electron

$q_2 = (\underset{= -e}{-1.6 \times 10^{-19} C})$

67. (cont.)

$$\therefore P.E. = \frac{k_o q_1 q_2}{r} = \frac{k_o (Z)(+e)(-e)}{r}$$

$$= -\frac{k_o Z e^2}{r}$$

Kinetic energy $= \frac{1}{2} m_e v^2$

from Angular Momentum: $L_n = m_e v r = \frac{nh}{2\pi}$

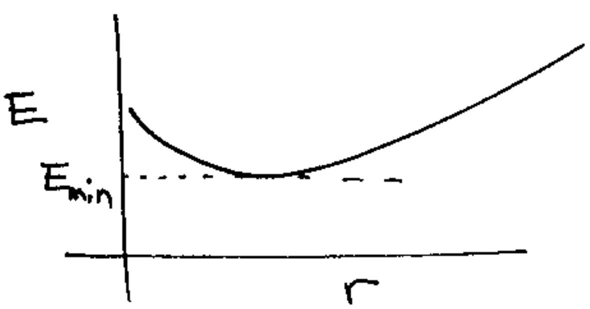
$$\Rightarrow v = \frac{nh}{2\pi m_e r}$$

$$v^2 = \frac{n^2 h^2}{4\pi^2 m_e^2 r^2}$$

$$\longrightarrow \frac{1}{2} m_e v^2 = \frac{\cancel{m_e}}{2} \frac{n^2 h^2}{4\pi^2 m_e^{\cancel{2}} r^2} = \frac{n^2 h^2}{8\pi^2 m_e r^2} = K.E.$$

$$E_{Total} = K.E. + P.E.$$

$$E(r) = \frac{n^2 h^2}{8\pi^2 m_e r^2} - \frac{k_o Z e^2}{r}$$ as required in book



E_{min} when $\frac{dE}{dr} = 0$ & $\frac{d^2E}{dr^2} > 0$

67. (cont.)

$$E(r) = \frac{n^2 h^2}{8\pi^2 m_e} r^{-2} - k_o Z e^2 r^{-1}$$

$$\frac{dE}{dr} = \frac{n^2 h^2}{8\pi^2 m_e}(-2) r^{-3} - k_o Z e^2 (-1) r^{-2} = 0$$

$$\frac{-n^2 h^2}{4\pi^2 m_e r^3} + \frac{k_o Z e^2}{r^2} = 0$$

$$\frac{k_o Z e^2}{r^2} = \frac{n^2 h^2}{4\pi^2 m_e r^3}$$

$$k_o Z e^2 = \frac{n^2 h^2}{4\pi^2 m_e r}$$

$$r = \frac{n^2 h^2}{4\pi^2 m_e (k_o Z e^2)} = \frac{h^2}{4\pi^2} \frac{n^2}{m_e k_o Z e^2} \quad \hbar = \frac{h}{2\pi}$$

$$r_{\text{min or max}} = \frac{\hbar^2 n^2}{m_e k_o Z e^2}$$

$$\frac{d^2E}{dr^2} = \frac{n^2 h^2}{8\pi^2 m_e}(-2)(-3) r^{-4} - k_o Z e^2 (-1)(-2) r^{-3}$$

$$= \frac{3 n^2 h^2}{4\pi^2 m_e r^4} - \frac{2 k_o Z e^2}{r^3}$$

67. (cont.)

$$\therefore \left.\frac{d^2E}{dr^2}\right|_{\substack{r=r_{min}\\ \text{or max}}} = \frac{3n^2h^2}{4\pi^2 m_e\left[\frac{h^2n^2}{4\pi^2 m_e k_o Z e^2}\right]^4} - \frac{2k_oZe^2}{\left[\frac{h^2n^2}{4\pi^2 m_e k_o Z e^2}\right]^3}$$

$$= \frac{3\cancel{n^2}\cancel{h^2}\left(\cancel{256}^{\,64}\,\pi^{\cancel{8}\,6} m_e^{\cancel{4}\,3} Z^4 e^8 k_o^4\right)}{\cancel{4}\cancel{\pi^2}\cancel{m_e}\, h^{\cancel{8}\,6} n^{\cancel{8}\,6}} - \frac{2k_oZe^2\left(64\pi^6 m_e^3 k_o^3 Z^3 e^6\right)}{h^6n^6}$$

$$= \frac{192\pi^6 m_e^3 Z^4 e^8 k_o^4}{h^6n^6} - \frac{128\pi^6 m_e^3 Z^4 e^8 k_o^4}{h^6n^6}$$

$$= \frac{(192-128)\pi^6 m_e^3 Z^4 e^8 k_o^4}{h^6n^6}$$

$$= \frac{64\pi^6 m_e^3 Z^4 e^8 k_o}{h^6n^6} > 0$$

$$\therefore r_{min\ or\ max} = \frac{\hbar^2n^2}{m_e k_o Z e^2} = \underline{r_{min}}$$

$$\therefore E_{min}(r=r_{min}) = \frac{n^2h^2}{8\pi^2 m_e\left[\frac{h^2n^2}{4\pi^2 m_e k_o Z e^2}\right]^2} - \frac{k_oZe^2}{\frac{h^2n^2}{4\pi^2 m_e k_o}}$$

67.(cont.)

$$= \frac{\cancel{n^3} h^2 (16 \pi^2 m_e^2 k_o^2 Z^2 e^4)}{\cancel{8\pi^2 m_e} h^{4\to 2} n^{4\to 2}} - \frac{k_o Z e^2 (4\pi^2 m_e k_o Z e^2)}{h^2 n^2}$$

$$= \frac{2\pi^2 m_e k_o^2 Z^2 e^4}{h^2 n^2} - \frac{4\pi^2 m_e k_o^2 Z^2 e^4}{h^2 n^2}$$

$$= \frac{(2-4)\pi^2 m_e k_o^2 Z^2 e^4}{h^2 n^2} = \frac{-2\pi^2 m_e k_o^2 Z^2 e^4}{h^2 n^2}$$

$$= \frac{-4\pi^2}{h^2} \frac{m_e k_o^2 Z^2 e^4}{2n^2}$$

$$E_{(n)\,\underline{min}} = \frac{-m_e k_o^2 Z^2 e^4}{2 \hbar^2 n^2}$$