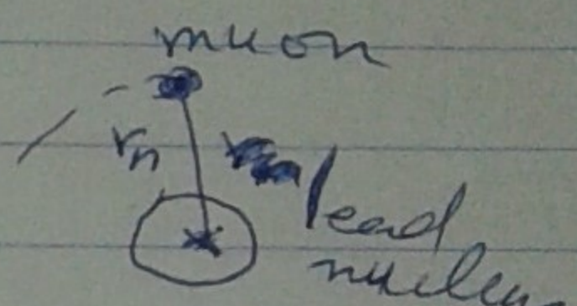
Problem 4-33 : Muonic Lead $\left(Z = 82 \text{ for } {}^{208}_{82}Pb\right)$

Muon : same as electron but $m_{muon} = 207\, m_e$

$$r_n = \frac{a_0 n^2}{Z(\mu/m_e)}$$



$$\mu = \frac{m_{muon} M_{nucleus}}{m_{muon} + M_{nucleus}} = 105.719\ MeV/c^2$$

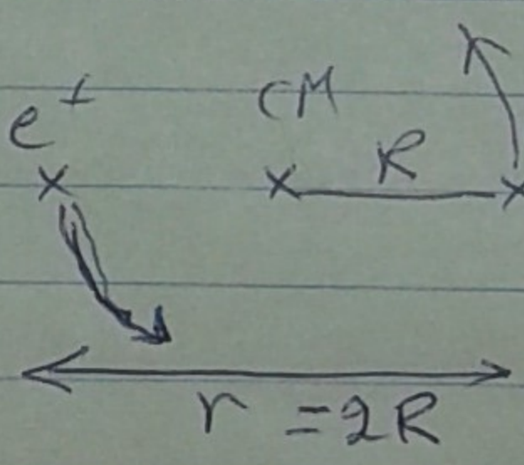
$$m_{muon} = (207)\, m_e = 105.777\ MeV/c^2$$

$$M_{nucleus} = (208)(931)\ MeV/c^2$$

(a) $$r_1 = \frac{0.529\,\text{Å}\ (1)^2}{(82)\left(\frac{105.719}{0.511}\right)} = \frac{0.529\,\text{Å}\ (1)^2}{(82)\ (206.886)} = 3.12 \times 10^{-5}\ \text{Å} = 3.12 \times 10^{-15}\ m$$

(b) $$E_1 = (-13.6\,eV)(207)(82)^2 = -18929404\ eV = -18.9\ MeV$$

Problem 4-35 : Positronium $= (e^+ + e^-)$ atom



$$\mu = \frac{m_e^2}{2m_e} = \frac{m_e}{2}$$

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

$$r_n \propto \frac{1}{\mu}$$

$$r_n = 2a_0 n^2$$

$$R_n = a_0 n^2$$

$$E_1 = -6.8\ eV$$

$$E_2 = -\frac{6.8}{4}\ eV = -1.7\ eV$$

$$E_3 = -\frac{6.8}{9}\ eV = \text{---}$$

etc

$$r_1 = 2a_0, \quad R_1 = a_0$$

$$r_2 = 8a_0, \quad R_2 = 4a_0$$

$$r_3 = 18a_0, \quad R_3 = 9a_0$$