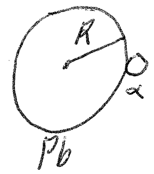
Prob. 1 Gold has an atomic number of Z = 79. What is the distance of closest approach for a 5.5-MeV alpha particle (α) in a head-on collision with a gold nucleus?

$$E_K = \frac{k(2e)(79e)}{R_{min}}$$

$$R_{min} = \frac{(9\cdot10^{9})(2)(79)(1.6\cdot10^{-19})^2\ N\cdot m^2}{(5.5\cdot10^{+6}\,eV)(1.6\cdot10^{-19}\,\frac{J}{eV})} = \boxed{4.14\cdot10^{-14}\ m}$$

Prob. 2 The nucleus of lead has a radius 7.10 x 10^{-15} m and an electric charge of 82e. What must be the minimum energy of an alpha particle in a head-on collision if it is to just barely reach the nuclear surface? Assume α particle radius is negligible



$e = 1.6\cdot10^{-19}\ C$

$$E_K = \frac{k(2e)(82e)}{R}$$

$$E_K = \frac{(9\cdot10^{9})(2)(82)e^2}{7.10\cdot10^{-15}}$$

$$E_K = 5.32\cdot10^{-12}\ J = 3.33\cdot10^{7}\ eV$$

$$E_K = \boxed{33.3\ MeV}$$

Prob. 3 Derive an expression for the velocity of an electron in the Bohr model of the atom, when the nuclear charge is Ze. Calculate the velocity as a fraction of the speed of light for Hydrogen (Z = 1) and lead (Z = 82). What do you conclude about the need for special relativity in describing electronic energies?

$$v^2 = \frac{n^2\hbar^2}{m^2 r^2} \quad \text{but} \quad r_n = \frac{\hbar^2 n^2}{kmZe^2} \quad \text{so}$$

$$v = \frac{n\hbar}{m}\left(\frac{kmZe^2}{n^2\hbar^2}\right) = \frac{kZe^2}{n\hbar}$$

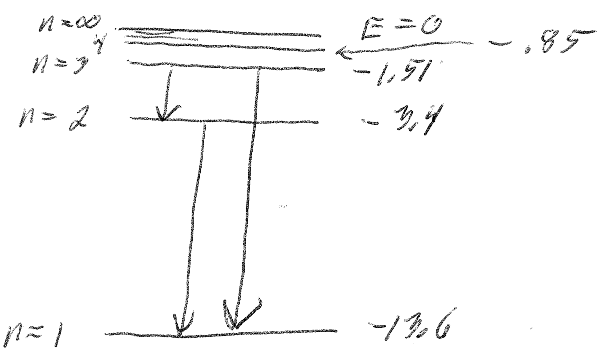
For $Z = 1$, $v = \frac{(9\cdot10^{9})(1.6\cdot10^{-19})^2}{6.63\cdot10^{-34}}\cdot 2\pi = 2.18\cdot10^{6}\ m/s = \boxed{7.3\cdot10^{-3}\ c}$

For $Z = 82$, $v = (82)(7.3\cdot10^{-3}c) = \boxed{0.6\ c}$

Need relativity for heavy nuclei

Prob. 4 A glass tube is evacuated and filled with low pressure hydrogen gas, and electrons are accelerated by a voltage V_o between electrodes in the tube. These electrons strike H atoms, exciting them to a higher energy level. If $V_o = 12.1$ V, what are the different wavelengths of the spectral lines emitted by the hydrogen?

Energy given to electrons is $E_K = 12.1$ eV



Max energy level excited is

$E = -13.6 + 12.1 = -1.5$ eV

This is just above level n = 3, so

n = 3 is highest level excited.

Three different energy photons can be emitted,

n = 3 → n = 2 $\quad \Delta E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.889$ eV

$\lambda = \frac{hc}{\Delta E} = \frac{1240 \text{ eV}\cdot\text{nm}}{1.889 \text{ eV}} = \boxed{656.5 \text{ nm}}$

n = 3 → n = 1 $\quad \Delta E = 13.6\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 12.09$ eV

$\lambda = \frac{1240}{12.09} = \boxed{102.6 \text{ nm}}$

n = 2 → n = 1 $\quad \Delta E = 13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 10.2$ eV

$\lambda = \frac{1240}{10.2} = \boxed{121.6 \text{ nm}}$