Chapter # 4 (H. W. Solutions)

Problem # 5:

a) $Z_1 = 2$; $Z_2 = 79$ & $\theta = 1°$

$$\rightarrow b = \frac{Z_1 Z_2 e^2}{8\pi \epsilon_0 K} \cot\left(\frac{\theta}{2}\right) = \frac{2 \times 79 \times (1.44 \times 10^{-9} eV \cdot m) \cot(\ldots}{2 \times (7.7 \times 10^6 eV)}$$

$$= 1.69 \times 10^{-12} m$$

b) For $\theta = 90°$

$$b = \frac{Z_1 Z_2 e^2}{8\pi \epsilon_0 K} \cot\left(\frac{\theta}{2}\right) = \frac{2 \times 79 \times (1.44 \times 10^{-9} eV \cdot m)}{2 \times (7.7 \times 10^6 eV)} \cot(\ldots$$

$$= 1.48 \times 10^{-14} m$$

* Problem # 11:

Here in all cases, the K.E. is changed into P.E.

i.e. $K = -\nabla V = |V| = \frac{Z_1 Z_2 e^2}{4\pi \epsilon_0 (r_1 + r_2)}$;

where $r_1, r_2 \rightarrow$ radii of the particles

a) $Z_1 = 2$; $Z_2 = 13$ for Al & $Z_2 = 79$ for Au

For Al : $K = \frac{2 \times 13 \times (1.44 \times 10^{-9} eV \cdot m)}{(2.6 \times 10^{-15} m) + (3.6 \times 10^{-15} m)} = 6.04$ Me\

For Au : $K = \frac{2 \times 79 \times (1.44 \times 10^{-9} eV \cdot m)}{(2.6 \times 10^{-15} m) + (7.0 \times 10^{-15} m)} = 23.7$ M

b) Now $z_1 = 1$ & for two different values of z_2

For Al : $$K = \frac{1 \times 13 \times (1.44 \times 10^{-9}\ eV \cdot m)}{(1.3 \times 10^{-15} m) + (3.6 \times 10^{-15} m)} = 3.82\ M$$

For Au : $$K = \frac{1 \times 79 \times (1.44 \times 10^{-19}\ eV \cdot m)}{(1.3 \times 10^{-15} m) + (7.0 \times 10^{-15} m)} = 13.7\ M$$

* Problem #16:

For H : $$v = \frac{e}{\sqrt{4\pi\epsilon_0 m r}} = \frac{e\,c}{\sqrt{4\pi\epsilon_0 m c^2 r}} = \frac{\sqrt{1.44\ eV \cdot nm}}{\sqrt{511 \times 10^3 eV \times 0.0529}} \times$$

$$= 7.30 \times 10^{-3} c = 2.19 \times 10^6\ m/s$$

$$\therefore\ a = \frac{v^2}{r} = \frac{(2.19 \times 10^6\ m/s)^2}{(5.29 \times 10^{-11}\ m)} = 9.07 \times 10^{22}\ m$$

& for H like Li^{++}:

$$F = \frac{Ze^2}{4\pi\epsilon_0 r^2} = \frac{mv^2}{r} \quad \text{or} \quad v^2 = \frac{Ze^2}{4\pi\epsilon_0 r m}$$

But also $$r = \frac{4\pi\epsilon_0 \hbar^2}{Zme^2} = \frac{a_0}{Z}$$

$$v^2 = \frac{Z^2 e^2}{4\pi\epsilon_0 a_0 m} = \frac{(3)^2 (1.44\ eV \cdot nm)}{(5.29 \times 10^{-11} m)(511 \times 10^3 eV/c^2)}$$

$$= 4.79 \times 10^{-4} c^2$$

or $v = \sqrt{v^2} = 2.19 \times 10^{-2} c = 6.57 \times 10^6\ m/s$,

which is a factor of 3 greater than speed for H.

$$\therefore\ a = \frac{v^2}{r} = \frac{(6.57 \times 10^6\ m/s)^2}{(5.29 \times 10^{-11}\ m)/3} = 2.45 \times 10^{24}\ m/$$

* Problem # 20:

As done in problem 16, $v = 2.19 \times 10^6$ m/s

& $L = mvr = (9.11 \times 10^{-31}\,kg)(2.19 \times 10^6\,m/s) \times (5.29 \times 10^{-11}\,m)$

$= 1.0554 \times 10^{-34}\ kg \cdot m^2/s$

Here notice that $L = \hbar$

* Problem # 25:

Generally the ground state energy is $Z^2 E_0$

a) $E = (1)^2 E_0 = 13.6$ eV

b) $E = (2)^2 E_0 = 54.4$ eV

c) $E = (4)^2 E_0 = 218$ eV

* Problem # 32:

The reduced mass for this system is

$\mu = mm/(m+m) = m/2$

where m is the mass of each particle.

Then $r = \frac{4\pi \epsilon_0 \hbar^2}{\mu e^2} = 2a_0$

$E = -\frac{e^2}{8\pi \epsilon_0 r} = -\frac{e^2}{8\pi \epsilon_0 (2a_0)} = -\frac{E_0}{2}$

$= -6.8$ eV