1) What is the cross-section (in barns) for alpha particle with kinetic energy of 8 MeV to scatter by 90 degrees or more from a gold nucleus? Consider a 2 mm diameter beam of 106 alpha particle per second incident on a gold target. There are 5.0x1017 gold nuclei in the beam area. How many alpha particles per second will scatter by more than 90 degrees?

Using 
\[ b = \frac{Z_1 Z_2 e^2}{8\pi \varepsilon_0 K \cot \frac{\theta}{2}} \]
where \( e^2/4\pi\varepsilon_0 = 1.44\times10^{-9} \text{ eV*cm} \)
and in this problem \( Z_1 = 2, Z_2 = 79, K = 8\times10^6 \text{ eV}, \theta = 90^\circ \)
plugging in these values yields:
\[ b = 1.422\times10^{-14} \text{ m} \]

The cross section is \( \sigma = \pi b^2 = 6.35\times10^{-28} \text{ m}^2 = 6.35 \text{ b} \)

The total scattering area is the area of the beam of alpha particles.
\[ A_T = \pi r^2 = (3.14)\times((0.001 \text{ m})^2) = 3.14\times10^{-6} \text{ m}^2 \text{ or } 3.14\times10^{22} \text{ b} \]

Effective area to scatter 90°: \( (5\times10^{17})\times(6.35 \text{ b}) = 3.176\times10^{18} \text{ b} \)

Probability to scatter 90° = (effective scattering area)/(total scattering area)
\[ = 1.011\times10^{-4} \]

Intensity of scattered alpha particles:
\[ (1.011\times10^{-4})\times10^6 \sim 101.1 \text{ alpha particles per second (90° scatter)} \]
3) What is the speed (v/c) of an electron in the first three Bohr orbits of the H atom? (Ch4 #22)

\[ V_n = \frac{1}{n^*} \frac{\mathcal{Q}}{m a_0} = \frac{1}{n^*} \frac{e^2}{4 \pi \varepsilon_0} = 2.2 \times 10^6 / n \text{ or } \{1/(n*137)\}^*c \]

\( n = 1: \quad \beta = \frac{1}{(1*137)} = 0.0073 \)

\( n = 2: \quad \beta = \frac{1}{(2*137)} = 0.0036 \)

\( n = 3: \quad \beta = \frac{1}{(3*137)} = 0.0024 \)

3) A hydrogen atom in an excited state absorbs a photon of wavelength 434 nm. What were the initial and final states of the hydrogen atom? (ch 4# 23)

\[ E = \frac{hc}{\lambda} = \frac{1240 \text{ eV*nm}}{(434 \text{ nm})} = 2.857 \text{ eV} \]

Original level is 2.857 eV or greater, so that leaves \( n = 1 \) or 2

\( n = 1 \rightarrow E = -13.6 \text{ eV} \)

\( n = 2 \rightarrow E = -3.40 \text{ eV} \)

The initial level \( n_{\text{int}} \) cannot be \( n = 1 \) because an energy jump of 2.857 is not allowed. \( n_{\text{int}} \) must be 2.

\[ E_f = E_i - \Delta E; \quad E_f = -3.40 \text{ eV} + 2.857 \text{ eV} = -0.54 \text{ eV} \]

Does 0.54 eV correspond to an acceptable energy level in the hydrogen atom? Yes, level 5. So an electron in level 2 was excited when a photon was absorbed by the hydrogen atom to level 5.

4) If a hydrogen atom is initially in the first excited state, what is the longest wavelength of light it will absorb? What is the shortest wavelength of light it will absorb?

The lowest excited state is \( n = 2 \). From problem #4 we know that this corresponds to an energy of -3.40 eV. When a photon is absorbed and an electron is excited to a higher energy state then the largest and smallest wavelength photons correspond to the lowest and highest energy transitions respectively.

Lowest energy photon that can be absorbed:

\( n = 2 \) jumps to \( n = 3 \) \[ \Delta E = 3.40 \text{ eV} - 1.51 \text{ eV} = 1.89 \text{ eV} \]

\[ \lambda_{\text{low}} = \frac{hc}{\Delta E} = \frac{1240 \text{ eV*nm}}{1.89 \text{ eV}} = 656 \text{ nm} \]

Highest energy photon that can be absorbed:
n = 2 jumps to n = ∞ (electron leaves nucleus and atom is ionized)
\[ \Delta E = 3.40 \text{ eV} - 0 \text{ eV} = 3.40 \text{ eV} \]
\[ \lambda_{\text{high}} = \frac{hc}{\Delta E} = \frac{1240 \text{ eV*nm}}{3.40 \text{ eV}} = 364.7 \text{ nm} \]

5) What is the calculated binding energy of the electron in the ground state of (a) deuterium, (b) He+, (c) Li++? (ch4# 25)

Starting with equation
\[ \frac{1}{\lambda} = Z^2 R \left( \frac{1}{n_l^2} - \frac{1}{n_u^2} \right) \]
where Z is the atomic number, using the reduced mass correction
\[ R = \frac{1}{\frac{m_e}{M}} R_{\infty} \]
where \( m_e \) is the mass of an electron (5.4858x10\(^{-4} \) amu), M is the mass of the nucleus and the Rydberg constant \( R_{\infty} \) has a value of 0.010974 nm\(^{-1} \)
and since this is a binding energy problem \( n_l = 1 \) and \( n_u = \infty \)

Also \( E = \frac{hc}{\lambda} \) so \( E = (1240 \text{ eV*nm}) Z^2 \)

deuterium: \( Z = 1, M = 2.01355 \text{ amu} \) → \( E = 13.6037 \text{ eV} \)
He+: \( Z = 2, M = 4.00151 \text{ amu} \) → \( E = 54.4222 \text{ eV} \)
Li++: \( Z = 3, M = 7.01436 \text{ amu} \) → \( E = 122.457 \text{ eV} \)

8) Extra credit 6-28
The gravitational force provides the centripetal acceleration \( v^2/r \), só
\[ F = G M e M p / r^2 = M e v^2 / r. \]
Manipulating this equation, we can find kinetic energy
\[ K = M e v^2 / 2 = G M e M p / (2r) \]
The potential energy of the system is \( U = -G M e M p / r \).
Thus \( E = K + U = -G M e M p / (2r) \).
Angular momentum \( L = M e v r = n \hbar \), só \( v = n \hbar / (M e r) \) and \( M e v^2 / 2 = M e (n \hbar / M e r)^2 / 2 \).
Then from equation (1), we can obtain \( M e (n \hbar / M e r)^2 = G M e M p / r \),
thus
\[ r n = (n \hbar)^2 / (G M e M e \hbar^2) = a_0 n^2. \]
Só we got \( a_0 = \hbar^2 / (G M e M e \hbar^2) = 1.2056 \times 10^{-29} \text{m} \).
\[ E_n = -G M e M p / (2 r n) = -(G M e M p)^2 M e / (2 n^2 \hbar^2). \]
Só the difference energy between n=2 and n=1 is
\[-(G\text{MeMp})^2 \text{Me}/(2 \ h^2)(1/4-1)=1.968*10^{-78}\text{ev}=3.15*10^{-97}\text{J}\]