PHYSICS 2102

Problem Set #4
Due: March 15, 2010

Please hand in your solutions at the start of class on the given date. Please staple all pages and attach a cover sheet with your name, student number, and the course name on it. Please show your work neatly. All Problems are from the text unless otherwise stated.

1. The wave function for an electron in the $2s$ state of a hydrogen atom is

$$\psi_{2s}(r) = \frac{1}{\sqrt{8\pi a^3}}\left(1 - \frac{r}{2a}\right)\exp(-r/2a), \tag{1}$$

   where a is the Bohr radius.
   (a) Find the radius r where the wave function has a peak value, in terms of a.
   (b) Find the value of r where the probability $P(r)$ of finding the electron has a maximum value? To do this, show that the radius of extrema of $P(r)$ are roots of the equation

$$r^3 - 8ar^2 + 16a^2r - 8a^3 = 0. \tag{2}$$

   The above polynomial equation can be factored into the form

$$(r - 2a)(r^2 - 6ar + 4a^2) = 0. \tag{3}$$

   The root $r = 2a$ corresponds to a local *minimum* in $P(r)$. The other two roots correspond to local maxima. Find the root which corresponds to the maximum value of $P(r)$. Show your reasoning. Compare the radius of maximum probability with the distance between nucleus and electron for the $n = 2$ state of the Bohr model.

2. Explain qualitatively why the $4s$ state of a multi-electron atom generally has a *lower* energy than the $3d$ state.

3. Problem 41.25.

4. Sodium (Na) has 11 protons in its nucleus and 11 electrons in orbitals. When the outermost electron is in the $3s$ state, measurements show that the energy to liberate the electron is 5.138 eV, so that the state has energy $E = -5.138$ eV. When the electron is in the $3d$ state, the energy is measured to be $E = -1.521$ eV. Calculate the value of Z_{eff} for each state. Which one of these states has an energy closer to that of an electron in the $3s$ state in a hydrogen atom? Explain why.

5. Problem 42.4.

6. Problem 42.8.

Practice problems:

Chapter 41 Problems 5, 6, 9, 13, 27, 31, 45.
Chapter 42 Problems 1, 3, 11, 13, 42.