Trent: PHYS 2620H – Atomic, Molecular and Nuclear Physics: 2009-2010

Midterm: Friday March 12, 2010

Allowed: Formula sheet (given), calculator, 1 hour 50 minutes
Answer all of Part 1 (worth 40% of the marks), and two out of the remaining three questions

Advice: Don't cram your answers into too small a space – explain your answers

Do all of this first question:

1.a) Consider a beryllium ion with all but one electron removed (a beryllium atom normally has 4 electrons). What is the wavelength of the transition from the first excited state to the ground state?

b) For the hydrogen atom in its ground state, the radial probability density is:

$$P(r) = 4(Z/a_0)^3 r^2 e^{-2Zr/a_0}$$

Make a rough sketch of this function and calculate the probability of finding the electron in the range $\Delta r = 0.04a_0$ at $r = 2a_0$.

c) Using the $\{n, \ell, m_\ell, m_s\}$ set of quantum numbers, write down all possible distinct quantum states for the hydrogen atom when $n = 5$. How many states are there in total?

d) The hydrogen atom and all one-electron ions exhibit an energy splitting of all non-s states. In one or two sentences, state the origin of this splitting, and provide an explanation for why s-states do not show this splitting.

e) A hydrogen atom is in the subshell $n = 4$, $\ell = 2$. What is a common name for this subshell, and how many electrons can it hold? What are all allowed possible values of *j*, the total electronic angular momentum quantum number?

Do two out of these three remaining questions:

2. Two of the wavelengths that a hydrogen atom can absorb are 97.5 nm and 102.8 nm. Deduce the set of possible principal quantum numbers that corresponds to these two transitions.

3. Write down the functional forms of the energy eigenfunction for an electron in the 3d, $m_\ell = +1$ state of the hydrogen atom, neglecting the effect of electron spin. Show that the expectation value of *r*, the distance between the electron and the nucleus, is $10.5\,a_0$, and compare it with the most probable value of this distance.

4. a) Consider putting two electrons into an infinite well of width *L*, with one electron in the first excited state, and the other in the second excited state. What *exchange symmetry* must be satisfied by these electrons? Write down an acceptable wavefunction for this state (you can treat the normalization constant as a parameter, *A*, if you wish).

b) Find the two allowed *terms* (i.e. each permitted set of *L* and *S*) for the 1s3d electron configuration of helium. For each term write down the symmetry of both the spatial and the spin parts of the two-electron wavefunction, and write down the precise forms of the spin parts of these wavefunctions. Which of the two terms lies lower in energy, and why?