2B22
QUANTUM PHYSICS &
QUANTUM FOUNDATIONS OF ASTROPHYSICS
PROBLEMS 5

To be handed in by ...

You may use

$$\int_0^\infty r^n \mathrm{e}^{-\alpha r} \mathrm{d}r = \frac{n!}{\alpha^{n+1}}$$

1. (a) Given that 1 atomic unit of energy is $4.3598 \times 10^{-18} J$, calculate the energies of the hydrogen atom in the states with principal quantum number $n = 2, 3, 4$.

   (b) Calculate the frequencies in Hertz, and the wavelengths in angstroms, of all the photons that can be emitted by the atom in transitions between these levels.

   (c) A sample of hydrogen atoms is prepared in the $4p$ state. At how many wavelengths will light subsequently be observed? How would the wavelengths differ if the atoms had been prepared in the $4s$ state?

2. An excited state of TiIII has two active electrons in the configuration 3d4p. Give the possible values of L, S, J which may arise, explaining your working.

3. A sample of hydrogen atoms are prepared in the $3p$ state. The probability for a transition to the $2s$ state is given by the expression:

$$P_{3p\to 2s} = \frac{2.026 \times 10^{18}}{\lambda^3} |\mathbf{M_{3p\to 2s}}|^{\mathbf{2}}$$

   where $M_{3p\to 2s}$ is the dipole matrix element for the transition and λ is the wavelength in angstroms.
   Assuming emitted radiation is polarized along the z axis, so $\epsilon.\mathbf{r} = r\cos\theta$, calculate the probability for this transition given that $R_{31} = (\frac{2}{3})^{3/2}\, r(1-r/6)\exp -r/3$ and $R_{20} = \frac{2}{2^{3/2}}\,(1 - r/2)\exp -r/2$.