Chemistry 542
Fall, 2002
Problem Set 9
Due Wednesday, November 20

Read Chapter 7. Most of this material should already be familiar to you.

1. Calculate the ratio of the transition probabilities for the following pairs of dipole transitions for the H atom.

A. $2s \rightarrow 3p$ vs $1s \rightarrow 2p$
B. $2p \rightarrow 3d$ vs $2s \rightarrow 3p$

2. Physicists love to think about circular atoms. Here is a problem illustrating some of their properties.

A. Write down the *radial* wave function for arbitrary *n* with *l* = *n*-1. Use the dimensionless variable $\rho = \frac{Zr}{a_0}$ and express the normalization constant as a function of n. In determining the radial function, recall that the number of nodes equals $n-l-1$. Feel free to use Table 6.1 for guidance, and show that you get the same result for n = 2 and n = 3.

B. Evaluate the transition dipole matrix element $\langle n, l = n-1 | r | n+1, l = n \rangle$ as a function of n.
C. Determine how the transition probability scales with

3. Which of the following pairs of radial wave functions are orthogonal? Justify your answer by evaluating the overlap integrals.
   A. {1s, 2s}
   B. {1s, 2p}
   C. {2s, 2p}

4. The associated Laguerre Equation is given by

$$xu'' + (\beta + 1 - x)u' + (\alpha - \beta)u = 0\,,$$

where α and β are integers. Its solution s are polynomials in x, denoted as $L_\alpha^\beta(x)$, where $x = 2\rho / n = \frac{2Zr}{na_0}$. Cast this equation in Sturm-Liouville form, and derive the orthogonality condition for $L_\alpha^\beta(x)$. In other words, find the weighting function. Compare your result with the radial eigenfunctions of the hydrogen atom.
5. How strong a magnetic field is needed to separate the H atom states $|l = 1, m = 1\rangle$

$\left| l = 1, m = 0 \right\rangle$ by one wave number

Levine 6.36.