1. **McIntyre 11.12** (*spin-1 and spin-1/2 system* )
2. **McIntyre 11.15 BUT use 3/2 and ½, not 1 and ½. Use Table 11.4 and not 11.3** (practice with tables of C-G coefficients)
3. **The relativistic correction to the H atom energy levels** (section 12.2.1) is a relatively straightforward application of perturbation theory. We will not discuss details of the derivation in class, but you are to work through the derivation:

(a) Show term-by-term how to get from Eq. 12.23 to 12.24. There is a step in the derivation that is not obvious. (How – exactly – do you deal with the $\langle n\ell m|H_0\frac{1}{r}|n\ell m\rangle$ ter

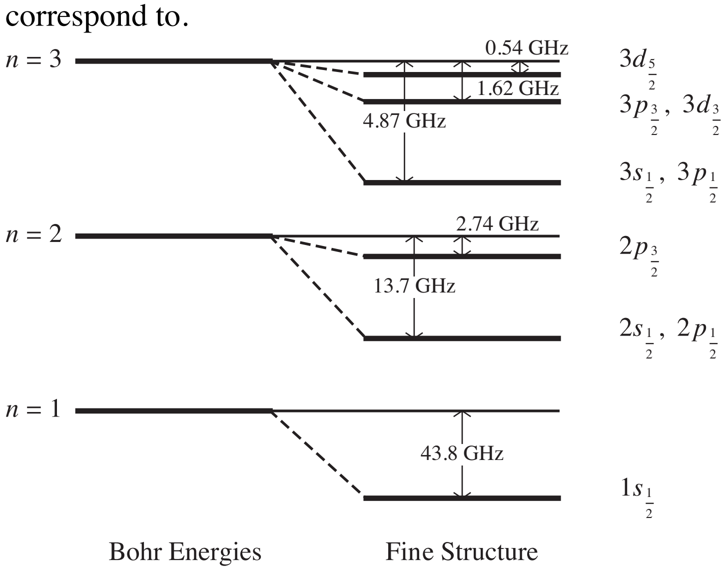
$|m_s = +1/2, m_I = +1/2\rangle$ m?)

(b) Eq. 12.24 gives the diagonal elements of $H'_{\mathrm{rel}}$. These diagonal elements are indeed the first-order corrections to the energy IF the matrix is diagonal in the degenerate sub-space of states of the same $n$ (i.e. degenerate unperturbed states.) Show that the <u>off-diagonal</u> elements within a particular degenerate subspace $n$ are zero. *i.e.* show: $\langle n\ell' m'|p^4|n\ell m\rangle = 0$ .

(c) Show that the formula 12.27 works for the $n$=2 states of hydrogen. Use Mathematica or similar, but show your working. Then assume that the general form stated is correct (too messy to prove in general).

(d) Then collect all the terms and show that 12.30 follows from 12.26.

4. **Explain the meaning of the terms** $3d_{5/2}$ *etc*. on the right of this table (Table 12.4 in your text). For the $3p_{3/2}$, $3d_{3/2}$ "coupled" states, calculate the total fine structure correction to the Bohr energy, and state explicitly which linear combinations of uncoupled states they correspond to.

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Finish any worksheets that were handed out in class (not to be turned in)
See over for some more comments

• You should be able to write down, without too much thought, the coupled and uncoupled basis states for any two types of angular momentum. This is the *starting* point for any problem.

• Note that Eqs. 12.42 & 12.43 and 12.83 feature the following statement:

$$\left\langle n\ell m_\ell m_s \right| \frac{1}{r^3}\mathbf{L}\cdot\mathbf{S} \left| n\ell m_\ell m_s \right\rangle = \underbrace{\left\langle \frac{1}{r^3} \right\rangle_{n\ell}}_{r\text{ only}} \underbrace{\left\langle \ell m_\ell m_s \right| \mathbf{L}\cdot\mathbf{S} \left| \ell m_\ell m_s \right\rangle}_{\phi,\theta\text{ only}}$$

The reason is that the $r$ integration is decoupled from the angular integration, so the LHS (which is really a triple integral over $r, \theta, \phi$) decouples into the product of two integrals, one over $r$ and the other over $\theta, \phi$).

• Please note the correction to Eq. 12.63 in your book:

$$\begin{array}{cc} L_z \doteq \hbar \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{3} & 0 & 0 & \frac{\sqrt{2}}{3} & 0 \\ 0 & 0 & \frac{-1}{3} & 0 & 0 & \frac{\sqrt{2}}{3} \\ 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & \frac{\sqrt{2}}{3} & 0 & 0 & \frac{2}{3} & 0 \\ 0 & 0 & \frac{\sqrt{2}}{3} & 0 & 0 & \frac{-2}{3} \end{pmatrix} & \begin{array}{c} \frac{3}{2},\frac{3}{2} \\ \frac{3}{2},\frac{1}{2} \\ \frac{3}{2},\frac{-1}{2} \\ \frac{3}{2},\frac{-3}{2} \\ \frac{1}{2},\frac{1}{2} \\ \frac{1}{2},\frac{-1}{2} \end{array} \end{array}$$

• Please note the correction to Eq. 12.86 in your book:

$$E_{fs}^{(1)} = \frac{1}{2}\alpha^4 mc^2 \left[ \frac{3}{4n^4} - \frac{\ell(\ell+1) - m_\ell m_s}{n^3 \ell(\ell+\frac{1}{2})(\ell+1)} \right]$$

Also check *ALL* the errata on the book web page.