Atomic & Molecular Physics Problem Sheet 2224.3
Issued Thursday 21 February 2008, due Thursday 28 February 2008

1. Describe the X-ray spectrum produced when a metal target is bombarded with electrons. Which features depend on the target, and which depend on the energy of the electrons?

   The table below contains some of Moseley's data from his experiments on X-ray spectra for the wavelength (λ) of a set of lines from the L series from various targets.

element	atomic number, Z	$\lambda_{\mathrm{L}}/10^{-8}$ cm
Antimony	51	3.245
Cerium	58	2.366
Samarium	62	2.008
Holmium	66	1.711
Tantalum	73	1.330
Osmium	76	1.201
Gold	79	1.092

Table 1: Moseley's data

   Following the method of Moseley, plot a suitable graph to find which line (α, β, etc) of the L-series the data corresponds, and assigna screening constant S that represents an average screening of the nucleus for the initial and final states for these L-series lines. **[10]**

2. The ground state of sodium is $^2\mathrm{s}_{\frac{1}{2}}$, while the first excited state is split by the spin-orbit interaction into two energy levels $^2\mathrm{p}_{\frac{1}{2}}$ and $^2\mathrm{p}_{\frac{3}{2}}$. Calculate the g-factors (g_j) for each of these states.
   Sketch a diagram of the splitting of the energy levels in a **weak** magnetic field. By comparing the change in energy produced by the Zeeman shift ($\simeq \mu_B B$) with the spin-orbit splitting of the excited state (17.2 cm^{-1}), deduce a criterion for the applied magnetic field, B, to be regarded as weak.
   Draw on your diagram the transitions allowed by the electric dipole selection rules. How many lines will be visible in the emission spectrum of sodium? **[10]**

3. If a two-level atom is exposed to a radiation field of spectral energy density $U(\nu)$ it may absorb energy and become excited at a rate $CU(\nu_{12})N_1$ and once excited decay due either to spontaneous or stimulated emission at rates AN_2 and $BU(\nu_{12})N_2$ respectively. Here $N_{1,2}$ are the populations of the lower and upper states, $U(\nu_{12})$ the energy density at the frequency of the transition between the states, and A, B and C and constants.

   By considering the steady-state, and thermal equilibrium between the atoms and the field, derive relations between the constants A, B and C.

   In a helium-neon laser the upper state of the laser transition is a 5s state lying 20.66eV above the ground state, and the lower state of the laser transition is a 3p state 18.70eV above the ground state. What is the wavelength of the photon emitted in this transition? If the output optical power of the laser is 2.5mW, how many photons per second are being emitted by the laser? **[10]**