ASTR 545
SPRING 2010
Homework 4
DUE: October 1, 2010

1. In class, we examined the MgII $\lambda\lambda 2796, 2803$ zero volt resonance transition, which results from the $^2\mathrm{S}_{1/2} - ^2\mathrm{P}_{3/2}$ and $^2\mathrm{S}_{1/2} - ^2\mathrm{P}_{1/2}$ state changes (transitions) of the ion, where we have invoked spectroscopic notation to describe the transitions.

   (a) From inspection of the MgII Grotrian diagram, note that there is also a 4p electron configuration with an excitation energy of roughly 9.99 eV. If the ground state electron were excited to the 4p configuration state, what are the quantum numbers (n, l, m, s) for this excited electron such that a transition between the ground state is allowed by the selection rules for multi-electron atoms? [There is more than one allowed transition.]

   (b) Write down the spectroscopic notations for these excited states of MgII. Write down the spectroscopic notation for the transitions between these excited states of MgII and the ground state of MgII. What are the changes ΔJ, ΔS, and ΔL for these transitions? Describe how these obey the dipole selection rules.

   (c) Examining the NIST data (table in the notes), report the wavelengths, Einstein coefficient, and oscillator strength corresponding to each transition. Also report the electron configurations, and statistical weights corresponding to the upper and lower energy level of each transition.

   (d) Consider the damping constants, Γ, for each of these two transitions. In the absence of a radiation field, and realizing that the transitions are to the ground state only, which of the two transitions do you expect to have the larger damping constant? How did you come to your conclusion (state your reasoning)? For this transition, compute ΔE of the upper energy level in ergs. Also compute the FWHM of the wavelength broadening $\Delta\lambda$ in angströms. Show your calculations.

   (e) You observe these transition in absorption in a spectrum. (i) If the equivalent widths, W, are weak (on the linear part of the curve of growth), what is the numeric value of the ratio W_b/W_r, where W_b is the equivalent width of the blue line (shorter wavelength) and W_r is the equivalent width of the red line (longer wavelength). Show your determination of this value. (ii) As the column density is increased such that the equivalent widths are on the flat part of the curve of growth, show (mathematically) that the ratio W_b/W_r converges to unity. [This ratio is known as the doublet ratio, and its value is commonly used to estimate where on the curve of growth the absorption is; the double ratio therefore provides a constraint on the column density of absorbers].

2. Consider the ion NII.

   (a) Write down the electronic configuration for the ground state of NII. Write down the quantum numbers (n,l,m,s) for the least bound (ground state) electron. What is the value of the excitation energy, χ, for this electron in eV? Write down the spectroscopic notation, ${}^{2S+1}\mathrm{L}_J$, for the ground state of NII.

   (b) Now consider the scenario in which the ground state electron is excited to the $n = 3$ shell via absorption. Considering the dipole transition selection rules for multi-electron atoms, there are several excited states from which the NII ion can *theoretically* transition between the ground state. Employing spectroscopic notation, write down these theoretically possible transitions. How many possible theoretical transition did you find?

   (c) Determine which of these transitions are actually physical (i.e., actually exist given the electron structure of atoms). To do this, begin by using the selection rules of multi-electron atoms to determine the l, m and s electron quantum states that the excited electron must have that yield an allowed transition to the ground state of NII [careful, unlike the Alkali IIA magnesium ion, the lower shell is not filled following excitation!). Show your work. From your results, which of the theoretically possible allowed transitions that you wrote down in part (b) exists for NII? For each of the excited states of NII that result in allowed transitions to the ground state, report the quantum numbers (n,l,m,s) of the excited electron.

3. Use NIST *http://physics.nist.gov/PhysRefData/ASD/lines_form.html* to look up the atomic data for the following transitions:

   (a) HeI λ4143

   (b) HeI λ4387

   (c) HeI λ4026

   (d) HeI λ4471

   (e) CaI λ4226

   (f) CII λ4267

   For each transition report the Einstein coefficient and oscillator strength. For the upper and lower energy levels of the transition, report the level energies, electron configurations, spectroscopic notation terms, and statistical weights. Write the spectroscopic notation of each transition. [You might present your results in a tabular form for clarity]

4. On the class web page, I have placed six (6) stellar spectra having resolution 5 Å. The files (named "starX.dat" or "starX.txt" are simple text files with two columns, wavelength in nanometers and flux density, f_λ, in units of erg s^{-1}cm^{-2} Å^{-1} times an arbitrary constant. They can be downloaded at

http://astronomy.nmsu.edu/cwc/Teaching/ASTR545/HW/spectra/

or on the ASTR 545 "Topics and Assignments" page.

(a) Plot each of the spectra (no more than two per page) from 340–680 nm (the data beyond that having missing wavelength coverage). I suggest two per page in landscape mode in order to expand the wavelength axis.

(b) Identify as many lines and/or features on each spectrum as you can and electronically label them on the plot (give the ion, transition wavelength of the feature, and a line connecting the feature and the label). If they are present: include (i) the Balmer decrement, (ii) the Balmer convergence, (iii) the Balmer limit, (iv) the individual Balmer lines, (v) the CaII H&K and NaI D_1&D_2 doublets, (vi) the CH (G-band) and MgH bands, (vii) the individual HeI lines, and (viii) any TiO bands.

(c) Using the "Arm Chair" classification method, provide an estimate of the Spectral Class of each star. Per the decision making flow chart, provide a statement of logic you applied to determined your most favored Spectral Class for each star.