Exam in atomic physics 1

Material: TeFyMa or a similar table, the formulae collection from the course and a calculator
Instructions: Each problem gives at most 4 points, after a holistic judgment, and you need a total of 12 and 19 points for a passing and an excellent degree, respectively. Your answers must be logical, well motivated and easy to read. Answers may be given in English or in Swedish

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1. K has 1 valence electron outside a closed Ar-shell and we write the ground configuration as 4s. The experimentally determined ionization energy is 35009.78 cm^{-1}. The levels in the 3 lowest excited configurations have the following excitation energies:

Level	E / cm^{-1}
4p $^2P_{1/2}$	12985.17
4p $^2P_{3/2}$	13042.88
5s $^2S_{1/2}$	21026.55
3d $^2D_{5/2}$	21534.68
3d $^2D_{3/2}$	21536.99

   a) Explain, using a simple atomic model, why the 4p- and 5s-electrons are more strongly bound than 3d.
   b) Estimate as well as possible the excitation energy of 5p $^2P_{3/2}$.
   c) Estimate as well as possible the fine-structure splitting in 5p

2. In the visible spectrum of gaseous nebula one usually finds 3 strong lines. One is the Balmer-beta transition in hydrogen (H_β) and the other 2 are so-called *forbidden* transitions in O III at 4960 and 5007 Å, respectively.
   a) Calculate the wavelength for H_β, which is the second line in the Balmer series. (You may check your value against tabulated results but you must do a calculation of your own!)
   b) The full-width-half-maximum for the observed H_β line is 0.35 Å. Determine the temperature of the nebulae if we assume that the line width is entirely due to the Doppler effect.

3. The resonance lines 3s ^2S - 3p ^2P in Na have the wavelengths 5889.6 and 5895.9 Å. Calculate the magnetic field required to make the energy of the highest magnetic sublevel in $^2P_{1/2}$ coincide with the lowest magnetic sublevel in $^2P_{3/2}$, under the (erroneous) assumption that the Zeeman formalism is still valid at such high fields.

4. From an absorption spectrum of the 0 - 2 vibrational transition in CO we determine the R_1 and P_1 transition wavenumbers as P_1 = 4256.06 cm^{-1} and R_1 = 4263.65 cm^{-1}. Use these data to derive the mean separation of the constituent atoms.

Please turn

5. Show schematically how the $1s^2 2s2p$ configuration first splits into *LS*-terms then into *J*-levels. Explain the physical interactions that are taken into account in the concepts *configuration*, *term* and *level*. You should give a fairly extensive but qualitative discussion.

6a. The components of the orbital angular momentum satisfy the commutator relations $[L_x, L_y] = i\hbar L_z$, $[L_y, L_z] = i\hbar L_x$ and $[L_z, L_x] = i\hbar L_y$. Use this together with the general mathematical result that $[AB, C] = A[B, C] + [A, C]B$ to show that $[L^2, L_z] = 0$.

6b. Explain the physical significance of the angular momentum commutator relations.