Exam in atomic physics 2

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.

Solutions will be posted on the home page after the exam.

Preliminary results (anonymous) will also be posted continuously as I grade your work

Remember not to have your phone with you during the exam!

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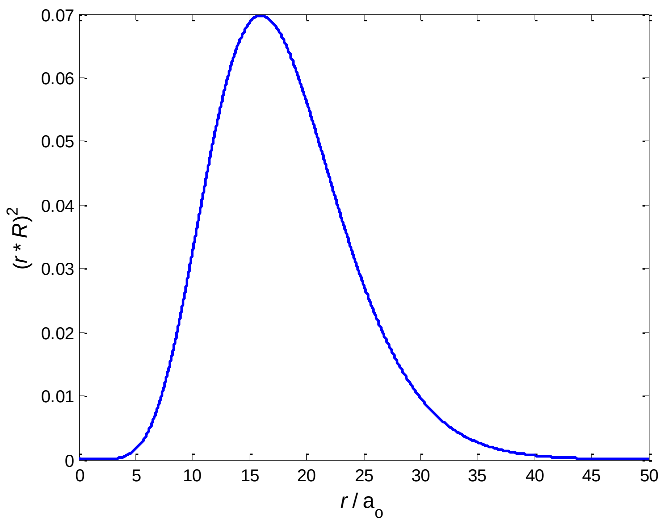
1. The figure below shows the radial probability distribution for an electron in H. In which orbital (n, ℓ) is the electron?



2. *Potassium*. The table (from NIST atomic data base) gives some energy data for K I

Configuration	Term	J	Level (cm^{-1})
$3p^6 4s$	^2S	$^1/_2$	0.0000
$3p^6 4p$	$^2P°$	$^1/_2$	12 985.185724
		$^3/_2$	13 042.896027
$3p^6 5s$	^2S	$^1/_2$	21 026.551
$3p^6 3d$	^2D	$^5/_2$	21 534.680
		$^3/_2$	21 536.988
K II ($3p^6$ $^1S_0$)	**Limit**	**---**	35 009.8140(7)

Estimate, as well as possible, the wavelength of the 4s ^2S – 20p ^2P (center-of-gravity) transition in K I.

3 The 5s5p $^3P_1$ - 5s6s $^3S_1$ transition in Cd gives rise to a blue line with the wavelength 4799.92 Å. The Cd lamp is placed in a homogeneous magnetic field of 0.5 T.

a) Draw a figure that shows the splitting of the blue line into Zeeman components. Use a relative energy scale, where zero is the transition energy without any magnetic field.

b) Give the polarization state of the components when viewed perpendicular to the field.

c) Calculate the smallest wavelength difference $\Delta\lambda_{min}$ between 2 Zeeman components, when viewed perpendicular to the field

4 We want to study the Zeeman structure in the previous problem using a Fabry-Perot interferometer capable of resolving $\Delta\lambda_{min}$ above. (If you don't have an answer to 3c, use $\Delta\lambda_{min}$ = 0.05 Å).

a) Assume that <u>both</u> the excited levels $^3P_1$ and $^3S_1$ have the same lifetime. What is the shortest lifetime the states could have if we want to resolve $\Delta\lambda_{min}$?

b) Which is the highest temperature that the light source could have if we want to resolve $\Delta\lambda_{min}$?

5. Use the derived relations between the Einstein coefficients to show:

a) That a non-statistical ("inverted") population is necessary to achieve laser action.

b) What happens to the momentum of an atom when it absorbs a photon?

6. Let's consider a new coupling scheme for 2 electrons, not treated in the lectures, namely *jK* coupling. Here we first couple $\hat{\ell}_1$ with $\hat{s}_1$ to $\hat{j}_1$ and then $\hat{j}_1$ with $\hat{\ell}_2$ to a new angular momentum that is usually denoted $\hat{K}$ and, finally, $\hat{K}$ with $\hat{s}_2$ to $\hat{J}$. What levels would we get in a 2p4d configuration in this model? Use the notation $j_1\,[K]_J$.

We use the *LS*-scheme when we believe that the largest correction to the central-field energy is the electrostatic repulsion of the 2 electrons followed by a much smaller spin-orbit interaction from each electron. We use *jj*-coupling when we believe that the largest correction is the spin-orbit energy of each of the 2 electrons followed by the much weaker electrostatic repulsion energy. What is the relative magnitude of the different interactions among the electrons if we would consider *jK* coupling?

Lars