Université de Nice Sophia-Antipolis Master 1: Optique - IMAG2E - MCS Anders Kastberg – Fabien Kéfélian

## EXAMEN

Physique atomique 2014–10–21, at 9:00–12:00

Aides autorisées:

- Photocopied pages from "Physics Handbook" (Nordling/Österman)
- Calculator

All calculations and arguments have to be clearly accounted for. Write your name on each submitted page.

 $Good\ Luck!$ 

- **1** The table below gives the wavelengths (in nanometers) for a number spectral lines observed for neutral hydrogen (H) and singly ionized helium  $(He^{+1})$ .
  - a. Label each spectral line with the principle quantum numbers associated with the transition in question.
  - b. Some wavelengths in the table are quite close to each other, but not exactly the same. Explain qualitatively where this difference comes from.
  - c. Can you say something quantitatively concerning the preceding question?

H (nm)	$\mathrm{He^{+1}}\ \mathrm{(nm)}$
656.28	656.01
486.13	541.16
434.05	485.93
410.17	454.16
	433.87
	419.99
	410.00

- 2 The neutral scandium atom has an excited configuration  $3d^24s$ .
  - a. Find all the allowed terms in this configuration.
  - b. How many fine-structure levels do each of these terms have? Write down all the fine-structure levels for all the terms.
  - c. How many of these levels have an allowed electric dipole transition to any of the levels in the ground configuration of Sc?

- **3** The principal isotopes of rubidium (Z = 37) are <sup>85</sup>Rb and <sup>87</sup>Rb.
  - a. To which family of elements does rubidium belong?
  - b. Give the electronic configurations of the ground state, and of the first excited configuration.
  - c. The ionization energy of rubidium is 4.2 eV. Give a quantitative estimate of the charge screening of the nucleus for the ground state (explain clearly your reasoning and how you define the charge screening value).
  - d. The transition between the ground configuration and the first excited configuration has a resonance frequency of 380 THz (ignoring fine structure). Use that information in order to estimate also the screening effect for the first excited state.
  - e. Determine the atomic terms for the two configurations in question. Note that the lowest energy term in the first excited configuration is the one with lower value of J.
  - f. For sodium (Z = 11), the fine structure is responsible for the well know yellow doublet, with the wavelengths 588.9950954 nm and 589.5924237 nm. In the case of potassium (Z = 19) the energy difference in the fine structure doublet is 57.7 cm<sup>-1</sup> in wavenumber units. From these data, estimate the fine structure spacing in rubidium (in any unit you want).
  - g. Show that there exist two allowed electric dipole transitions within the levels considered.
  - h. We now take into account the hyperfine structure. What is the origin of hyperfine structure?
  - i. We first consider the transition with the shortest wavelength (780 nm) for the isotope <sup>85</sup>Rb. Due to the hyperfine structure there are 6 allowed different transitions near 780 nm. Explain this result, taking into account that the nuclear spin quantum number for <sup>85</sup>Rb is I = 5/2.
  - j. For  ${}^{87}\text{Rb}$ , the hyperfine structure of the highest energy term in the first excited configuration has 4 hyperfine structure levels, with the following spacing between them (in frequency units): 72 MHz, 157 MHz, and 267 MHz. Find the value of the hfs quantum number F for each level, and also the value of I for  ${}^{87}\text{Rb}$ .

*Hint:* the magnetic dipole hyperfine structure hamiltonian is:

$$H_{\rm hfs} = A_{\rm hfs} \, \mathbf{I} \cdot \mathbf{J}$$