

# Introduction to Atomic Physics

## Lab Report

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## 1 Theory

### 1.1 Atomic structure and electron energies

Atoms are build up by a positive core and negatively charged electrons circulating around it. The wave functions of the electrons are distinguished by their quantum numbers, which in the Bohr model for hydrogen are given by the principal number  $n$ , the orbital angular momentum  $l$  and its  $z$ -component  $m_l$ , the spin  $s$  and its  $z$ -component  $m_s$ .

In fine structure theory relativistic effects are taken into account. That is a relativistic correction to the kinetic energy, a coupling between spin angular momentum and orbital angular momentum, and the Darwin term. As the hamiltonian of the spin-orbit coupling does not commute with the operators  $L_z$  and  $S_z$ ,  $m_l$  and  $m_s$  are no longer good quantum numbers. Instead we use the total angular momentum  $j$  and its  $z$ -component  $m_j$ .

Depending on the quantum numbers, the electrons have different energies. According to the Bohr model for hydrogen, the energies only depend on the principal quantum number  $n$ : The energy increases for larger  $n$ . The fine structure removes some of this degeneracy: According to this, the energy also depends on the the total angular momentum  $j$ . Again the energy increases with the total angular momentum.

If the spin of the nucleus is taken into account, the energy becomes dependent on this as well, giving rise to the hyperfine structure. Quantum electro dynamics also gives rise to a shift in energy depended of the quantum number  $l$ . These effects are not relevant in this exercise.

### 1.2 Many electron atoms and transitions

Other atoms than hydrogen has many electrons circulating around the nucleus which interact with each other. The inner electrons (with low  $n$  and  $l$  values) are 'screening' the positive nucleus from the outer electrons, which are thereby looser bound to the atom. The higher  $n$  and  $l$  the electrons have, the farther away the electron is from the nucleus and the larger will this screening effect be. The energy of the electrons will thus increase for higher  $l$ . The a Grotrian diagram for sodium can be seen in figure 2.

It is possible for an electron to make a transition between two quantum states through emission of a photon. As the photon has a spin of 1, there must be a difference in orbital angular momentum of 1 between the two states:  $\Delta l = \pm 1$ . The emitted photons have

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