# Elements of the Structure of Matter

## Prof. Luigi Sangaletti

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

To provide knowledge of the most significant experiments carried out in the study of the electronic structure of atoms. To explain the theoretical models developed to describe and interpret the experimental data. To apply the basic notions of quantum mechanics to solving problems regarding the electronic structure of atoms (spin-orbit coupling, sum of angular momenta, Zeeman and Paschen-Back effects and hyperfine structure).

The intended learning outcomes are the ability to discuss radiation-matter interaction in atomic systems (both in the UV-VIS and X-ray domain), the vector model of the atom and its use in spectroscopic problems in magnetic fields of different intensities, the solution approaches to the problem of multi-electron atomic systems (variational principle, Hartree method, use of Hartree Fock wave functions), and the determination of the multiplet structure in LS and jj coupling schemes.

***COURSE CONTENT***

* Radiation-matter interaction. Two-level system perturbation theory. Electric dipole transition rules. Absorption, stimulated and spontaneous emission of radiation. Einstein coefficients. Spectral lineshape and width.
* Electronic structure of atoms. Bohr’s model applied to hydrogenic and muonic atoms, as well as to positronium. Isotope effects. Solution of the Schrödinger equation for the hydrogen atom.
* Removal of orbital decay in alkali atoms. Orbital angular momentum and spin. Spin-orbit coupling. Fine structure. Atoms in a magnetic field. Lande’s factor. Zeeman effect and Paschen-Bach effect. Selection rules for optical transitions.
* The helium atom. Ground state and the variational principle. Hartree and self-consistent field approaches. Composition of angular momenta. L-S coupling. j-j coupling. Atoms with several electrons. Pauli exclusion principle and symmetry of many-electron wavefunctions. Slater’s determinant. Many-electron atoms and the periodic table of elements. Hund's rule. Exchange integral. Atomic multiplets. Equivalent electrons. Clebsch-Gordan coefficients.
* Nuclear spin and hyperfine structure. Effect of the nucleus on atomic spectra. Spin and magnetic moment of atomic nuclei. Hyperfine interaction. Hyperfine structure in an external magnetic field.
* X-rays and the structure of matter. X-ray production: Bremsstrahlung radiation and characteristic emission. X-ray spectra. Moseley’s law. Crystalline structure and X-ray diffraction. Elastic diffusion of X-rays by electrons. Compton scattering. Bragg's law. Crystal diffraction. Matter waves and the De Broglie wavelength.

***READING LIST***

 - H. Haken e H. C. Wolf, *The Physics of Atoms and Quanta,* , Springer Verlag, 2005.

 - R. Eisberg e R. Resnick, *Quantum Physics of Atoms,* Molecules, Solids, Nuclei and Particles, Wiley, 2nd ed 1985

- B.H. Brandsen - C. J. Joachain, *Physics of Atoms and Molecules,* Prentice-Hall, London (2003).

- D. J. Griffiths, *Introduction to Quantum Mechanics,* Trad. Italiana, Introduzione alla Meccanica quantistica, Casa Editrice Ambrosiana, Milano (2005).

***TEACHING METHOD***

Lectures (20 hours)

Class exercises (20 hours)

***ASSESSMENT METHOD AND CRITERIA***

Preliminary written examination followed by an oral examination. The written examination is composed of 5 exercises on the course main topics, as presented during class exercise sessions. The 5 exercises have to be solved in two hours. Each exercise is worth 6 points maximum. Access to oral examination is provided by a rating of the written examination of at least 18 points. The oral examination is aimed to assess the level of knowledge of the main topics of the course, the ability to present them and the student’s mastering of these concepts to discuss problems in the field of atomic physics. The overall mark is composed of the written examination (weight = 1/3) and the oral examination (weight = 2/3) outcomes.

***NOTES AND PREREQUISITES***

*Further information can be found on the lecturer's webpage at http://docenti.unicatt.it/web/searchByName.do?language=ENG or on the Faculty notice board.*