Magnetism of atoms – quantum-mechanical basics

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The magnetism of materials can be derived from the magnetic properties of atoms. The atoms as quantum objects subject to the laws of quantum mechanics. Therefore, the magnetism of materials possesses the quantum nature. In my lecture, I will give a brief introduction to the basics of quantum mechanics and introduce the notions of quantum states, quantum numbers, wave functions, eigenvalue equations, energy levels, and electronic shells. The most essential magnetic properties of atoms result from the orbital magnetic moment of electrons and the spin magnetic moments of electrons and atomic nuclei. These magnetic moments are closely related to the orbital motion of electrons and the fact that the electrons, protons, and neutrons possess spins. I will present the solutions of the eigenvalue equations for the orbital momentum of the electron and for its spin and demonstrate how they lead to the discrete energy spectra of atoms in an external magnetic field. The solutions of the energy eigenvalue equation (Schrödinger equation) will be presented for the hydrogen atom. I will discuss the applicability of the one-electron approximation to the many-electron atoms. The shell filling in the many-electron atoms can be explained on the basis of the Pauli exclusion principle and Hund's rules, which leads to the construction of the periodic table of elements. I will analyse the spin states of two-electron systems and introduce the concept of exchange interaction, which allows us to understand the different magnetic properties of materials. I will derive the spin-orbit coupling from the relativistic electrodynamics and discuss its role in spintronics. In a summary, I will point out to some new perspectives of the magnetism of atoms.