

The framework for hyperfine interactions (VIP1) : short summary

(automated transcription)

The question we want to answer here is, what is the energy of a system of electrons and nucleons? And nucleons can be either protons or neutrons. We will be interested only in eigenstates of the system, which is roughly equivalent to states that are stable for at least a short amount of time. As a reference energy, we take the situation when all the electrons and all nucleons are at rest and far away from each other at infinite distances. The energy of that state of the system we call zero. Now the strongest interaction is between the nucleons. They will condense to form a nucleus. Depending on how exactly they do interact, that system, that nucleus, can have different energies. And typical energy differences between different states of the nucleus are keV to meV. The electrons are still taken to be at infinite distances away from each other and away from the nucleus. Now the electrons are brought closer to each other and closer to the nucleus such that they can interact. And this lowers the energy of the system by some eV. For every type of nucleus there is one lowest energy configuration of the electrons and that is called the ground state configuration for that nucleus. The electron cloud does not have to be in that ground state, however it can be excited and every excited state can have its own energy. The maximal energy of the system for a given nucleus is then when the electrons are infinitely away from that nucleus. If we zoom in on any of these energy levels we can identify several states that are typically meV apart from each other. This is called the fine structure. These states differ from each other by how the overall spin of the electron cloud is oriented with respect to the overall angular momentum of the electron cloud, a phenomenon that is called spin-orbit interaction. And if we zoom in even more then any of these fine structure levels appears to be split into hyperfine structure levels. These are only microelectron volts apart from each other. They depend on how the nucleus is oriented with respect to the electron cloud and a nucleus can have different orientations only if it is not a pure point charge, which means it should have a spin and or it should have a non-spherical shape.