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II–18 Magnetic HFS of Muonic Atoms with Polarized Nuclei

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Static magnetic moments in the closed shell region have revealed the anomalous orbital g-factor due to the mesonic exchange current.[1] The magnetic hfs of muonic atoms especially of Bi will give further information on the role of this effect.[2] So far, the hfs coupling constants, A_1, for the muonic $1s_{1/2}$ and $2p_{1/2}$ states of Bi have been measured,[3] but because of too small hfs splitting they are not accurate enough. Aiming at precise determination of the A_1's, we propose an experiment using a polarized ^{209}Bi target and polarized muons, where we want to populate selectively one of the two F states by changing the relative polarization direction. A practical polarized ^{209}Bi target is realized as bulk material in a form of the BiMn compound. A complete polarization can be attained by use of a dilution refrigerator and a 5 kG external field.[4] Let us examine briefly how different profiles of splitting of the $2p_{1/2} \rightarrow 1s_{1/2}$ X-ray are expected.

The population of the $2p_{1/2}$ state originates mostly from the upper Bohr orbitals of $J = l - 1/2$, the polarization of which is, according to Mann and Rose,[5] $\langle J_z \rangle / J = -1/3$ with respect to the full polarization of muon beam. In the subsequent cascades muons feel almost no depolarization until they enter the level where the quadrupole splitting is greater than the natural width. Here, there may be a strong depolarization both of muon and target spins, but it is only the selective population of F quantum number that we are concerned with. The population parameters of sublevels designated by F that is only a good quantum number can be calculated successively once the initial muon and target polarizations are given. We assume that the quadrupole hfs is switched on at the $3d_{3/2}$ level, and we obtain the population of the $F = 4$ and 5 states ($J = 1/2$ and $I = 9/2$) as follows.

$$\langle \text{Para} \rangle \quad \rho(4):\rho(5) = 0.6:0.4$$
$$\langle \text{Anti} \rangle \quad \rho(4):\rho(5) = 0.3:0.7\ ,$$

where ⟨Para⟩ means that the target polarization is along the initial muon beam direction and ⟨Anti⟩ is the reversed case. Then the transition intensities are calculated, as illustrated in Fig. 3 of ref. 6. Because of this large difference we hope to obtain the coupling constants 4 times more precisely than in the unoriented case.

References

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