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VII-2 Hyperfine Anomaly in ^{151}Eu and ^{153}Eu

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As has been known for a long time, the ratio of the hyperfine splitting constants of two nuclear levels $R(A) = A_1/A_2$ is not necessarily equal to the ratio of the g factors $R(g) = g_1/g_2$. According to Bohr and Weisskopf[1] this is due to the difference in interaction energy of the spatial extended nuclear magnetic moment with a homogeneous and an inhomogeneous magnetic field at the nuclear site. Normally hyperfine fields are inhomogeneous because they contain contribitions being produced by core polarization which essentially gives rise to a net s electron density at the nucleus. On the other hand, externally applied fields as used in NMR measurements of g factors are homogeneous at the nucleus.

In this work the existence of both, a homogeneous and an inhomogeneous hyperfine field in different europium containing compounds is used to measure the hyperfine anomaly between ground and excited nuclear states in ^{151}Eu and ^{153}Eu.

In europium iron garnet (EuIG) crystal field states with $J \neq 0$ are mixed to the originally unmagnetic $^7F_0$ ground state of the trivalent europium ion by the iron exchange interaction to produce a hyperfine field at the europium nucleus of +600 kOe.[2] So this field is produced by the induced orbital angular momentum and is thus homogeneous over the nuclear volume. Taking divalent europium-oxide EuO or EuS, the Eu^{2+} ion is in an $^8S_{7/2}$ ground state with a core polarization hyperfine field of −325 kOe. So Mössbauer measurements of the 21.5 keV transition in ^{151}Eu and of the 103.2 keV transition in ^{153}Eu in EuIG and EuO, EuS are performed to measure the hyperfine anomaly of these states.

As results from these measurements we deduce

$$R^{151}(g) = 0.5332(4), \qquad R^{153}(g) = 2.222(6)$$
$$R^{151}(A) = 0.5376(4) \quad \text{and} \quad R^{153}(A) = 2.182(14).$$

From these values hyperfine anomalies of

$$^{o}\Delta^{22} = -0.81(8)\% \text{ for } ^{151}\text{Eu}$$
and
$$^{o}\Delta^{103} = +1.8(8)\% \text{ for } ^{153}\text{Eu}$$

can be deduced by employing the definition $\Delta = 1 - R(A)/R(g)$.

For an interpretation of these results the hyperfine anomaly has to be calculated using appropriate nuclear models. In the case of ^{151}Eu this is not quite easy because of the difficulty of applying one of the current nuclear models as those nucleus stands at the borderline of the strongly deformed nuclei being only weakly deformed as shown by the small quadrupole moment.[3] Therefore in Table I results obtained by using all current nuclear models are given. As is thus demonstrated, best agreement with experiment is obtained with the single particle shell model, whereas the Nilsson model even does not give the right sign. In the case of ^{153}Eu the situation is easier due to the large deformation of $\delta = 0.31$[4] indicating the applicability of the Nilsson model. Using Reiner's[5] calculation of the anomaly, a value of $^{o}\Delta^{103} = 0.8\%$ and $^{o}\Delta^{103} = 0.99\%$ is obtained using the model values for g_I and the experimental ones, respectively. The agreement between experiment and theory is, however, not as good as in ^{151}Eu because of the relatively large anomaly indicating nearly equal contributions of spin and orbital moment of the odd nucleon to the nuclear moment, both contributions being of different sign thus producing a large anomaly. To account for such big anomalies more detailed knowledge of the nuclear structure than available in the moment is necessary.

Table I. Theoretical estimates of Δ for ^{151}Eu; Δ^{mod} are calculated with the model values of g_I, Δ^{exp} with the experimental g_I.

Nuclear model	Δ^{mod}	Δ^{exp}
Homogeneous charged sphere[1]		−0.58%
Single particle model	−0.73%	−0.87%
Asymmetric model[6]	−2.12%	−0.93%
Nilsson model	+3.27%	+1.36%
Core excitation model[7]	−1.45%	−1.43%

References

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