Investigation of Statistically Perturbed Angular Correlations of $^{154}$Gd and $^{156}$Gd in Different Liquid Sources

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The statistical perturbations of $\gamma\gamma$-angular correlations involving the first $2^+$ rotational state of $^{154}$Gd and $^{156}$Gd have been time differentially investigated. We used liquid sources of $3^+$ ions of Gadolinium in 1N perchloric acid, 0.5N and 1N hydrochloric acid, 1.3N and 2.6N sulfuric acid. Influences of the various chemical surroundings on the ratio $\lambda_4/\lambda_2$ of the attenuation parameters have been found. A simultaneous measurement of the angular correlation of the $874 \text{ keV} - 123 \text{ keV}$ cascade and the $2,098 \text{ keV} - 89 \text{ keV}$ cascade of $^{154}$Gd and $^{156}$Gd, respectively, has been performed in perchloric solution. From the ratio of the attenuation parameters $\lambda_2$, obtained by this experiment, we have derived the ratio of the magnetic $g$-factors of the first $2^+$ levels of these isotopes as $g^{154}\text{Gd}/g^{156}\text{Gd} = 1.11 \pm 0.08$.

1. Introduction

In three previous publications we have reported about systematic studies of statistically perturbed angular correlations in liquid sources of the rare earth nuclei $^{160}$Dy, $^{166}$Er and $^{172}$Yb [Ref. 1-3]. As a result of these investigations we have found that the time behaviour of the angular correlation coefficients $A_2(t)$ and $A_4(t)$ can be well described by an attenuation according to the theory of Abragam and Pound 4, 5:

$$A_k(t) = A_k(0) e^{-\lambda_k t}.$$

In this equation $\lambda_k$ are the attenuation parameters which are proportional to the interaction frequencies and the correlation times of the perturbing influences.

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Furthermore we have concluded from our experiments that in the case of these isotopes the statistical perturbation is in a very good approximation only due to the fluctuating fields of the unfilled 4f electronic shell. Influences of the chemical composition of the sources could not be observed within the accuracy of the experiments. Thus we were able to calculate the spectroscopic quadrupole moments of the first 2+ rotational states of $^{160}$Dy and $^{172}$Yb.

In order to investigate more precisely the chemical influences on the attenuation of angular correlations of rare earth nuclei we have enlarged our experiments on Gadolinium. In this element the 4f electronic shell has an $^8S_{7/2}$ configuration and thus one expects no electromagnetic fields from the own atomic shell at the nuclear site, which could cover the influences of the liquid environment.

This expectation is only true in a first approximation since one can calculate and also observe a magnetic field of about 331 kGauss at the site of the nucleus which is produced by core polarisation. Since this field is smaller by a factor of 10 against the magnitude of the magnetic fields of the other rare earth ions, the influences of the environment become more important on the perturbation of the angular correlation than in the case of the isotopes investigated previously.

Because of the $S$-state of the 4f shell the atom has a high symmetry which gives rise to an extremely long relaxation time of the electronic shell compared to the other rare earth ions. For this reason the statistical perturbation can be described by a very long correlation time which is of the order of $10^{-10}$ s. This value can be compared with the lifetime of about $10^{-9}$ s of the $2^+$ rotational state of this deformed nucleus. Thus in addition deviations from the theory of Abragam and Pound might be possible to observe in the case of Gadolinium.

2. Experiments

In order to study chemical influences on the attenuation of the angular correlation we have performed time differential measurements in liquid sources by using different anorganic acids: 0.5 N HCl, 1 N HCl, 1.3 N H$_2$SO$_4$, 2.6 N H$_2$SO$_4$, and 1 N HClO$_4$. These acids were chosen because of their different behaviour in forming mixed complexes as pointed out in Ref. 1. Since these complexes give rise to electric field gradients at the nuclear site, the electric hyperfine interaction frequencies should be

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