Hyperfine Fields on Recoil Implanted Nuclei
62 ≤ Z ≤ 74 in a Polarized Fe-, Co- and Ni-environment

R. BRENN, L. LEHMANN, and H. SPEHL
Physikalisches Institut der Universität Freiburg i. Br., Germany
Received October 19, 1967

Hyperfine fields acting on Sm, Gd, Dy, Er, Yb, Hf and W nuclei in a polarized ferromagnetic environment of Fe, Co and Ni have been investigated. The nuclei have been implanted into the host lattice by the recoil associated with Coulomb excitation with 11 MeV C12-ions from a 5.5 MV Van de Graaff accelerator. The precession of the γ-ray angular distribution has been measured and substantial perturbations were found. It is shown that the perturbation, at least for the case of the strongly perturbed rare earth nuclei, cannot be explained by a combined static electric quadru-
pole and magnetic dipole interaction.

1. Introduction

In the last years Recoil Implantation of excited nuclei into any desired environment has been used, in connection with perturbed γ-ray angular distributions, to investigate perturbation mechanisms and to measure internal magnetic fields. The method has been introduced by FLAMM and ASARO1 using the recoil of a preceding α decay. KLEPPER and SPEHL2 measured internal perturbations of a γ-ray angular distri-
bution following a (p, p') reaction. Recoil Implantation has also been used in g-factor measurements by GOLDRING et al.3 by letting the Coulomb excited nuclei recoil into a suitable environment of low per-
turbation. BORCHERS et al.4 and BOEHM et al.5 were the first to measure internal magnetic fields acting on host nuclei in a polarized ferromagnetic environment. High energy heavy ion Coulomb excitation has been used and coincidence with backscattered projectiles has been shown to be feasible. The high anisotropy of the γ-ray angular distribution connected with this special excitation geometry and the high recoil energy in forward direction is especially suitable for high internal field precession measure-
ments.

* Work supported by Bundesministerium für wissenschaftliche Forschung.
2 KLEPPER, O., and H. SPEHL: Nuclear Phys. 64, 393 (1965).
The precession measurements reported here have been carried out by Coulomb excitation with 11 MeV C$^{12}$-ions from the Freiburg 5.5 MV Van de Graaff Generator. With such low energy, coincidence with back-scattered projectiles is no longer feasible. A complication arises due to the fact that even for very thin targets there is only a probability $p < 1$ for the recoiling nuclei to leave the target layer. There are always some nuclei recoiling close to 90° with respect to the beam being stopped in the target. This means that a term has to be added to the angular distribution which shows no precession. Rather high uncertainties seem to be introduced because the escape probability $p$ cannot be calculated with good accuracy. It will be shown however that (within some limits) the γ-ray angular distribution is very insensitive to the target thickness.

2. Angular Distribution and Precession

The angular distribution of γ-rays following $E2$ Coulomb excitation by scattering at a definite angle $\theta_p$, $\varphi_p$ is given in a general form by Alder et al.\(^6\) Eq. (II.66). For the special case of axial symmetry needed here, the distribution has to be integrated over the azimuthal angle $\varphi_p$. The result can be written in the form\(^7\)

$$W(\theta, \varphi) = 1 + c_2(\theta, \xi) \cdot A_2 \cdot P_2(\cos \theta) + c_4(\theta, \xi) \cdot A_4 \cdot P_4(\cos \theta).$$

(1)

Here $A_2 = 0.3571$, $A_4 = 1.143$ for a $0^+ \rightarrow 2^+ \rightarrow 0^+$ sequence, $c_2$ and $c_4$ are particle parameters depending on the scattering angle $\theta_p$ and the parameter $\xi$ which characterizes the Coulomb excitation process\(^6\). In Fig. 1 $c_2$ and $c_4$ are given for the special case $\xi = 0.3$.

In order to calculate the γ-ray angular distribution in our geometry one has to proceed in two steps: 1. Calculation of the target escape probability $p$ of the excited recoiling nuclei. This involves knowledge of range-energy relations\(^8\) and differential Coulomb excitation probabilities\(^6\). The result of a numerical calculation is given in Fig. 2b as a function of the dimensionless parameter $d/\sigma_{\text{max}}$, where $d$ is the target thickness and $\sigma_{\text{max}}$ is the range of a nucleus with highest possible recoil energy (head on collision). 2. One has to bear in mind that the γ-ray angular distribution is different for the parts $p$ and $(1-p)$ of excited nuclei. For a finite target thickness $d$, mainly those nuclei are escaping from the target which are recoiling in forward direction. This means that by taking the average over the scattering angles $\theta_p$ the right hand side

