Nuclear Magnetic Resonance on Oriented Nuclei: Resonance Shift with the External Magnetic Field ◇

G. Seewald, E. Hagn, and E. Zech

1. Motivation

The technique of nuclear magnetic resonance on oriented nuclei (NMR-ON) allows precise determinations of the magnetic hyperfine splitting frequency $\nu_{\rm M}$ of radioactive nuclei in a ferromagnetic host lattice,

$$\nu_{\rm M} = |\, g\mu_{\rm N} B_{\rm HF}/h\,|\,, \tag{1}$$

where g is the nuclear g-factor and $B_{\rm HF}$ is the magnetic hyperfine field. In an external magnetic field $B_{\rm ext}$ the NMR-ON resonance frequency is given by

$$\nu = \nu_{\rm M} + |\,g\,|\ \mu_{\rm N} B_{\rm ext}(1+K) sgn(B_{\rm HF})/h. \tag{2}$$

Here $sgn(B_{\rm HF})$ is the sign of $B_{\rm HF}$ with respect to $B_{\rm ext}$, and K is the "resonance shift parameter" taking into account Knight shift, diamagnetic shielding and other effects. In experiment, the resonance frequency ν is measured for different values of $B_{\rm ext}$, and, assuming a linear dependence between $\nu(B_{\rm ext})$ and $B_{\rm ext}$,

$$\nu = [\nu(B_{\rm ext}=0)] + [d\nu/dB_{\rm ext}]\, B_{\rm ext}, \tag{3}$$

$\nu(B_{\rm ext}=0)$ and $d\nu/dB_{\rm ext}$ are determined with a *least squares* fit. Under the assumption that $\nu_{\rm M}$ of eq. (2) does not depend on $B_{\rm ext}$ the comparison of eqs. (2) and (3) yields

$$|\, gB_{\rm HF}\,| = \nu(B_{\rm ext}=0)\, h/\mu_{\rm N} \tag{4}$$

and

$$|\,g\,|\ (1+K) = |\, d\nu/dB_{\rm ext}\,|\ \ h/\mu_{\rm N}. \tag{5}$$

Thus, if $B_{\rm HF}$ is experimentally known, the nuclear g-factor can be determined from $\nu(B_{\rm ext}=0)$ via eq. (4). Eq. (5) can then be used to determine K. On the other hand, if K is known, the g-factor can be determined from the resonance shift via. eq. (5), independent on the knowledge of $B_{\rm HF}$. As the resonance shift parameters in the literature show large scatterings, the question arises to what precision g-factors can be determined reliably via the resonance shift. Therefore it was viewed necessary to remeasure the resonance shift for all systems for which the respective literature values were doubtful. In the framework of new experiments on magnetic moments of Tc-isotopes [1] it became evident that only the system Rh**Fe** seemed to be an exceptional case with an anomalous resonance shift. Therefore new NMR-ON experiments on $^{101\rm m}$Rh in Fe and Ni were performed.

2. Experiments and Results

Samples of $^{101\rm m}$Rh ($I^\pi = 9/2^+$, $T_{1/2} = 4.3$d) in Fe and Ni were prepared by recoil implantation at the cyclotron in Karlsruhe via the reaction ^{104}Pd(α,xnyp) with $E_\alpha = 96$ MeV. The samples were cooled to ~ 10 mK with a ^{3}He-^{4}He-dilution refrigerator. The NMR-ON measurements were performed in an external magnetic field up to 20 kG, Typical spectra are shown in Fig. 1.

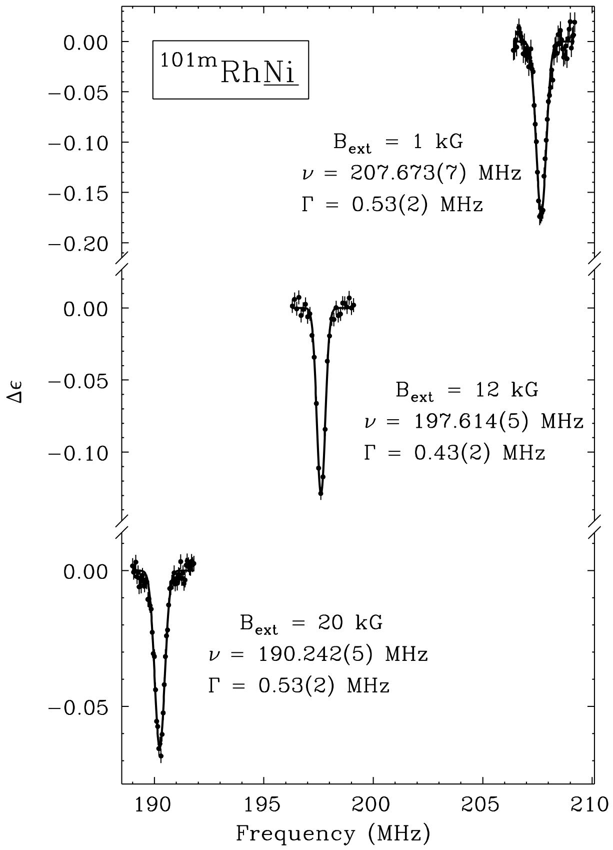

Fig. 1: NMR-ON resonances of $^{101\rm m}$Rh in Ni.

Taking the literature value for the hyperfine field of Rh in Fe we get

$$\begin{aligned} K_{\rm Fe}^{\rm (Rh)} &= -0.009(4); \\ K_{\rm Ni}^{\rm (Rh)} &= -0.009(3); \\ K_{\rm Fe}^{\rm (Rh)} - K_{\rm Ni}^{\rm (Rh)} &= +0.001(3). \end{aligned}$$

The negative K values for Fe *and* Ni together with the small difference between $K_{\rm Fe}^{\rm (Rh)}$ and $K_{\rm Ni}^{\rm (Rh)}$ *could* point to an erroneous hyperfine field which is fixed by the g-factor of $^{100\rm m}$Rh and the hyperfine splitting of $^{100\rm m}$RhFe. Nevertheless, $|K| \leq 10^{-2}$ is fulfilled. Thus the literature values for K which grouped around of $\sim -5\%$ must have been erroneous. A full description of this work is given in Ref. [2].

References

[1] B. Hinfurtner et al. Z.Phys. **A350** (1995) 311
[2] G. Seewald et al. Phys.Rev. **B51** (1995) 11484

◇Work supported by the DFG under the contract number Ha 1282/3-3 and by the Forschungszentrum Karlsruhe