It is probable that diffusion will be too small to be measured at temperatures where processes other than the simple six-jump process may be ignored. The more complicated processes which will come into play at slightly higher temperatures would not, however, be expected to change the ratio G very greatly. We may therefore reasonably expect that, at low temperatures, the two diffusion constants will lie within a factor of two or three of one another and this expectation is borne out by the experimental results.[4]

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Effective Nuclear Spin Interactions in Ferromagnets

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THIS note is to draw attention to a type of nuclear spin-spin interaction which may be at the root of the difficulty of observing nuclear resonance of the metal nuclei in ferromagnetic and antiferromagnetic insulators.

The interaction takes place as follows: Each nuclear spin sees the electronic spin on its own ion, through the effective hyperfine coupling $A\mathbf{I}\cdot\mathbf{S}$. The electronic spins of all the ions are coupled by exchange interaction. An interaction of the nuclei therefore arises via the low-lying excited states (spin waves) of the electronic system as intermediate states.[1–4] That is to say, a nuclear spin excites a spin wave through the hyperfine coupling, and another nuclear spin causes it to be reabsorbed through its hyperfine coupling. For a cubic ferromagnet, summation of this process over all the possible virtual spin-wave states leads to a nuclear interaction of the form

$$\mathfrak{H}_{\text{eff}}=-\frac{A^2S}{8\pi g\mu_BH_{\text{ex}}}\sum_{i\neq i}\frac{a}{r_{ij}}\exp\left[-\left(\frac{H_{\text{int}}}{H_{\text{ex}}}\right)^{\frac{1}{2}}\frac{r_{ij}}{a}\right]I_i^-I_j^+, \tag{1}$$

where r_{ij} is the distance between sites i and j, a the lattice spacing, A the hyperfine coupling constant, S the ionic spin, H_{ex} an effective exchange field, H_{int} the effective dc field (i.e., the applied steady field minus the demagnetizing field). $I_i^{\pm}$ stands for $I_i^x\pm iI_i^y$, where I_i^x, I_i^y are the nuclear spin components in a plane normal to the quantization direction, which is taken to be the direction of H_{int}. Demagnetization effects (other than in H_{int}) were neglected, the energy of a spin wave quantum of wave number k being taken in the form $\hbar\omega_k=g\mu_B(H_{\text{int}}+H_{\text{ex}}a^2k^2)$. If demagnetization effects are included, interactions of the form $I_i^+I_j^+$ and $I_i^-I_j^-$ will also occur, leading to satellite lines. The self-energy term $i=j$, which has been omitted from (1), gives a small shift in the nuclear resonance frequency, and, if $I>\frac{1}{2}$, also a small quadrupole effect.

The interaction (1) will lead to a nearly Gaussian line profile,[5] with root-mean-square width given by Van Vleck's formula.[6] Since the range of the interaction is rather long (about 30 lattice spacings for $H_{\text{ex}}\sim10^6$ oe and $H_{\text{int}}\sim10^3$ oe), the sum in Van Vleck's formula[6] may be replaced by an integral, with the result

$$\langle(\Delta\nu^2)\rangle^{\frac{1}{2}}=S\left[\frac{I(I+1)}{24\pi}\right]^{\frac{1}{2}}\left(\frac{H_{\text{ex}}}{H_{\text{int}}}\right)^{\frac{1}{4}}\left(\frac{A}{h}\right)\left(\frac{A}{g\mu_BH_{\text{ex}}}\right). \tag{2}$$

For example, in the Mn^{++} ion, with $S=\frac{5}{2}$, $A=10^{-2}\,\text{cm}^{-1}$, $I=\frac{5}{2}$, and $H_{\text{ex}}/H_{\text{int}}=1000$, the line width will be about 0.14 Mc/sec.

Formula (2) is very similar [aside from the factor $(H_{\text{ex}}/H_{\text{int}})^{\frac{1}{4}}$] to the result of Moriya[7] applicable in the paramagnetic regime. Thus, the hope that ferromagnetic ordering of electron spins might make observation of nuclear resonance easier than it is in the disordered state does not appear to be justified.

The same process also occurs in antiferromagnetic materials such as MnF_2 and affects the resonance of the nuclei of both the magnetic and nonmagnetic ions. The result is much the same as (2) with the anisotropy field replacing H_{int}. This, and related topics, will be discussed in a forthcoming paper.

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Possible Method for Determining the Intrinsic Parity of the K Meson*†

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AS a consequence of the nonconservation of parity in the weak interactions, including decays not involving the emission of neutrinos, there is no possibility of determining the intrinsic parity of a K meson or hyperon by observations on its decay.[1] However,