felt that the observed rapid falloff in attenuation implies a mean-free-path of normal electrons in the superconducting state that decreases with temperature.[6,8]

Our results for indium, however, suggest that the falloff in attenuation below the superconducting transition may not be the rapid, yet continuous, decrease previously assumed. We feel that our results can be described adequately by assuming a discontinuous drop of about 40% in attenuation as the transition temperature is passed; the remaining attenuation apparently decreases with temperature as T^3. Such an empirical description is indicated in Figs. 1 and 2 by the solid lines. An assumed T^3 dependence gives a good fit to all the experimental points except those within 0.02°K of the transition temperature. The latter points are within the magnitude of spread one would expect of the transition temperature.

Such an interpretation, if further results continue to support it, changes considerably the theoretical basis of any explanation of the phenomenon. It implies: (a) A partial decoupling of the normal electrons from the ultrasonic lattice motions in the presence of any superconducting electrons. This could result if some of the coupling were due to electric fields. (b) If the remaining temperature-dependent attenuation is due to normal electrons, whose concentration in the superconducting state varies as T^4, then their effective mean-free-path below the transition temperature would be proportional to T^{-1}. Such a dependence may prove to be more amenable to theoretical explanation than that of a mean-free-path which decreases very rapidly with temperature, as has been assumed previously.

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Ferromagnetic Relaxation and Gyromagnetic Anomalies in Metals*

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In spite of several suggestions, the mechanism of electron spin-lattice relaxation in ferromagnetic metals is imperfectly understood. It has even been doubted that any intrinsic relaxation process is sufficiently effective to give a significant line width in ferromagnetic resonance. In this Letter we propose a new mechanism which may contribute to relaxation in all ferromagnetic metals, and which would appear further to account for both the apparent frequency dependence[1] of the observed g-values and the apparent inaccuracy of the theoretical connection between microwave and magnetomechanical studies.[2]

We consider specifically pure Fe, Co, and Ni; here the magnetization is associated with $3d$ electrons in a sea of $4s$ conduction electrons. Whether or not one agrees with Zener[3] that the exchange coupling of the $3d$ ion cores with the $4s$ electrons is the dominant interaction responsible for ferromagnetism, it seems reasonably certain that such an exchange interaction does exist in these metals.[4] In the free atoms the relevant exchange energy is of the order of 0.5 ev. As long as there are incompletely filled $3d$ and $4s$ bands, we may expect to have a significant interaction, which will be of the form $A\mathbf{S}\cdot\mathbf{s}$, where $\mathbf{S}$ is the spin of a $3d$ ion core and $\mathbf{s}$ the spin of an electron in the $4s$ conduction band.

The $3d$–$4s$ exchange interaction contributes to the resonance line width. Before estimating the relaxation frequency we deal with the argument that an interaction $\mathbf{S}\cdot\mathbf{s}$ cannot contribute to relaxation. The argument is that $\mathbf{S}\cdot\mathbf{s}$ commutes with the total spin $\mathbf{S}+\mathbf{s}$ and thus cannot affect the time dependence of the total magnetization. If, however, the conduction electron spin is relaxed independently by a rapid mechanism,[5] then in a ferromagnetic resonance experiment we are observing the resonance of $\mathbf{S}$ alone, and the above injunction is no longer pertinent.

The effect may also be illustrated by simple extension of results[6] on relaxation processes in a system of two spins. If we take a perturbation $\mathbf{S}\cdot\mathbf{I}$ and add a relaxation process characterized by the relaxation frequency ρ for the system I alone, Solomon's equation (9) becomes

$$d\bar{I}_z/dt=-(w_0+\rho)(\bar{I}_z-I_0)+w_0(\bar{S}_z-S_0); \qquad (1)$$

$$d\bar{S}_z/dt=w_0(\bar{I}_z-I_0)-w_0(\bar{S}_z-S_0). \qquad (2)$$

Here w_0 is the transition probability arising from the perturbation; S_0, I_0 refer to thermal equilibrium. In the limit of rapid $4s$ relaxation $\rho\gg w_0$, so $\bar{I}_z\cong I_0$ and $d\bar{S}_z/dt \cong -w_0(\bar{S}_z-S_0)$, showing that w_0 governs the relaxation of $\mathbf{S}$. This is confirmed by the actual solutions of (1) and (2).

The $A\mathbf{S}\cdot\mathbf{s}$ interaction leads to a shift in the resonance somewhat analogous to the Knight shift in nuclear resonance. It will be shown in detail in a subsequent publication that in a molecular field approximation the interaction may be expressed as an extra internal fixed H_i acting on the $3d$ magnetization, where

$$H_i=AM_s/4\mu_B^2N_s; \qquad (3)$$

here the $4s$ magnetization M_s is

$$M_s=3AS\mu_BN_A/4E_F, \qquad (4)$$

where N_s, N_A are the concentrations of $4s$ electrons and of ion cores. E_F is the Fermi energy of the 4s electrons. Thus

$$H_i = 3A^2 S N_A / 16\mu_B E_F N_s. \qquad (5)$$

Now if H_i should be $\approx$ 100 to 500 oersteds, it would help eliminate the apparent frequency dependence of the g-values in metals and it would also help lower the values of g and thus bring them into better agreement with the theoretical relation $g-2 \approx 2-g'$. We need $A \approx 10^{-2}$ ev to give $H_i = 300$ oersteds, according to Eq. (5); on this estimate $M_s \approx 1$ gauss and is not itself a major source of magnetization. The suggested value of A is of the order of magnitude we expect after correction for screening.[4]

The relaxation time may be estimated by making appropriate modifications in the calculation by Abrahams[7] of the magnetic dipolar interaction between spin waves and conduction electrons in metals. We would expect our interaction to increase his relaxation frequency by a factor $\approx (A/4\pi M\mu_B)^2 \approx 10^4$ for iron, and this is confirmed approximately by doing the calculation. The resultant relaxation time for iron is of the order of 10^{-8} sec at room temperature, and this is indeed the observed order of magnitude.

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Hyperfragment Production

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The detailed solution of the problem of Λ^0 fragment formation in heavy nuclei probably requires a knowledge both of the properties of Λ^0 particles and of the mechanism of production of the fragments. We still lack this knowledge; however, it seems possible to justify some of the features of the phenomenon with the simple model that we shall describe.

When an energetic particle (nucleon, meson) hits a heavy nucleus (Ag or Br in emulsion), Λ^0 particles are produced with cross section σ_Λ. There is good evidence[1] that a sizable fraction f of the Λ^0's do not leave the nucleus immediately, but are slowed down by collisions with the nucleons in the nucleus to the Fermi energy of the nucleons. So, of the N neutrons in the nucleus, the fraction

$$p_\Lambda = \sigma_\Lambda f / \sigma_g N$$

is replaced by Λ^0 particles. The cross section for interaction with the nucleus is assumed equal to the geometrical cross section, σ_g.

TABLE I. Z spectrum of hyperfragments.

Z	3	4	5	6	7	8	9	10
$100n(Z)$	10	54	12	10	3	5	3	3
$\frac{(A-Z)n(Z)\times 27}{\Sigma(A-Z)n(Z)}$	2	11	4	3	1	2	2	2
Λ^0 fragment production[a] in emulsion	6	6	5	7	0	3	0	0

[a] Average of hyperfragments produced by pions, protons, and cosmic rays.[6]

We now assume that p_Λ is also the probability that a Λ^0 is substituted for one of the neutrons in a fragment coming out of the star. The justification for this assumption rests on the fact that the slowing down of the Λ^0 particle in the nucleus takes place together with the subdivision of the energy of the primary particle among the nucleons in the nucleus, so that the probability of Λ^0 capture by a fragment does not depend strongly on the energy of the fragment.

This point of view is valid only for fragments with charge $Z \geq 3$, which show a binding energy for Λ^0 approximately equal to that of neutrons; it is not valid for $Z=1$ and 2, which show instead binding energies substantially smaller.[2] If $n(Z)$ is the average number, per star, of fragments of large Z, hence containing $A-Z$ neutrons, the probability of formation of an excited fragment of charge Z is then

$$P(Z) = (A-Z)p_\Lambda n(Z) = \frac{\sigma_\Lambda f}{\sigma_g} \frac{(A-Z)n(Z)}{N}.$$

Jastrow[3] has calculated $\sigma_\Lambda f$, utilizing the elementary cross sections and the Monte Carlo method. For π-mesons of 1.5 and 2 Bev and protons of 3 Bev on Ag, he found $\sigma_\Lambda f \sim 15$ mb. For protons, this is obtained if one assumes a cross section per nucleon for Λ^0 production comparable to that of the pions, i.e., ~ 1 mb.[4]

The fragment production of these stars, following Perkins,[5] is given by the second row of Table I.

With these values, and $\sigma_g = 1300$ mb, one obtains

$$\sum_{Z=3}^{10} P(Z) = \frac{\sigma_\Lambda f}{\sigma_g N} \sum_{3}^{10} (A-Z)n(Z) \sim 10^{-3}.$$

This compares favorably with the values, for all fragments with $Z \geq 3$, found by Fry[6] for both protons of 3