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FERRIMAGNETIC RESONANCE LINE WIDTHS AND *g*-FACTORS IN FERRITES

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A theory of resonance g-factors[1] and line widths[2] for the rare earth garnets which gives reasonable agreement with all available experimental data has recently been developed by Kittel, Portis, and de Gennes. The purpose of this Letter is to extend the above theory to other magnetic systems, in particular the spinel-type ferrites.

The KPdeG theory hinges on the demonstration that (1) a lattice of ions (the rare earths) exhibiting a relaxation frequency high compared to all other frequencies involved in the motion will contribute a precessing magnetization to the system but essentially no coherently precessing angular momentum, and (2) an ion of very high relaxation frequency, exchange-coupled to a precessing low-loss magnetic system, will effectively scatter energy out of a uniform precession and into shorter spin waves.

The extension of the theory rests upon two further observations: (1) that the rapidly relaxing ions need not be sequestered onto a distinct sublattice to exhibit the properties cited above, and (2) that certain ions of very short relaxation time do indeed commonly occur in ferrites.

Any of the transition elements whose lowest lying state in an octahedrally or tetrahedrally coordinated site of cubic symmetry is not an orbital singlet is a candidate for the role played by the rare earth ions in the rare earth garnets. In particular, Fe^{2+}, Co^{2+}, and Mn^{3+} in octahedrally coordinated sites and Fe^{2+}, Ni^{2+}, or Mn^{3+} in tetrahedrally coordinated sites will possess such energy levels, since these ions will then have ground states which are orbital doublets or triplets split only by spin-orbit interaction or crystal field components of lower symmetry. Fe^{2+}, most likely the principal source of line width in ferrites generally, has been observed in the paramagnetic state[3] to have a short relaxation time T_1 even at reduced temperatures ($T_1 = 5\times10^{-9}$ sec at 20°K, $T_1 = 10^{-10}$ sec at 80°K). As pointed out by KPdeG, the relaxation time T_1 is theoretically inversely proportional[4] to H^2 and may be further greatly shortened by the enhancement of the applied field by the exchange fields; i.e., T_1 may be several orders of magnitude shorter in the ferrites than in a diamagnetic host.

Several general features of the available data on ferrites tend to confirm the hypothesis that the KPdeG relaxation process is a dominant one in these materials:

1. Magnetite, Fe_3O_4, which certainly contains Fe^{2+} ions, shows a very wide (2000-3000 gauss) resonance line.

2. Yttrium iron garnet, which should contain exclusively Fe^{3+} ions (ground state, orbital singlet) and essentially no Fe^{2+} ions, shows exceedingly narrow ($\Delta H < 0.5$ gauss) resonance lines.

3. A maximum in line width as a function of temperature is observed in iron-rich manganese and manganese-zinc ferrites. This maximum is characteristic of motionally narrowed resonances and is expected in this case when the relaxation frequency of the spin scattering ion becomes commensurate with the precession frequency of the system.

4. The addition of small amounts of Zn^{2+}, unambiguously divalent, to iron-rich manganese ferrite greatly reduces the observed resonance line width. It is suggested that divalent zinc reduces the concentration of divalent iron.

5. A high degree of correlation exists between large magnetic anisotropy and large resonance line widths (single crystal) in the ferrites. In the present theory the same low-lying energy levels which give rise to magnetic anisotropy[5] tend to

give rise also to short relaxation times, and the correlation is expected.

It is also possible that the resonance g-factors observed in the ferrites can be understood on the basis of the momentum-quenched ions. If, for instance, the Fe^{2+} ions occur preponderantly on the octahedral sites, the quenching of their angular momentum will cause the net effective g-factor to be raised, in accord with the experimental observation that the g-factors for the ferrites are usually somewhat greater than one would expect. It is probable, however, that the above argument on the g-factors should for the present be regarded with some suspicion inasmuch as ad hoc assumptions concerning ion distributions are being invoked.

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INTERACTIONS OF 1.15-Bev/c K^- MESONS IN EMULSION*

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We have exposed a large stack of Ilford K.5 emulsion to the 1.15-Bev/c separated K^- beam developed by Good and Ticho.[1] By area scanning we have located some 600 interactions with emulsion nuclei. This report deals with two groups of data: (A) an unbiased sample of 102 interactions, and (B) a selected group of interactions which produced more than one prong near the minimum of ionization or which gave evidence of strange-particle production in the plate in which the event was located.

The results of this study are as follows: (a) clear evidence for the reactions $K^- + N \to \pi + \pi + Y$ and $K^- + N \to K^- + N + \pi + \pi$; (b) evidence for the reaction $K^- + N + N \to Y + Y + K^0$ or $K^- + N \to \Xi^- + K^0$ followed by $\Xi^- + N \to Y + Y$; (c) a possible case of a "cascade hyperfragment," that is, one which contains two units of negative strangeness; (d) no cascade particle or K^+ meson was definitely identified.

(A) Analysis of an unbiased sample of 102 stars.— The interactions studied in this portion of our analysis include all of the events located in a single pellicle. Based upon the relative populations of $K:\pi:\mu$ in the beam as estimated by Alvarez et al.,[1] we estimate that 93% of these stars were produced by K^- mesons.

In Table I we summarize the salient features of this analysis.

All the particles produced in these interactions were followed until they came to rest (594), or interacted, decayed, or left the emulsion stack (74). In only a few cases were the tracks not suitably oriented for analysis.

It is recognized that area scanning could bias our prong distribution toward large stars. The

Table I. Summary of analysis of 102 stars.

K^-	Prong distribution		Distribution of reaction products							
Bev/c	Mean	Mode	H.F.	$\Sigma^\pm$	2π	1π	$\pi^\pm$	$(K^-)_{\text{inelastic}}$	Stable	π^+/π^-
1.15	6.5	5	7	25	7	35	49	3	584	9/19