SPIN GLASSES AND MICTOMAGNETS - REVISITED

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Abstract
A critical survey of the extensive experimental data for spin glass alloys is undertaken with the aim of drawing some basic conclusions and indicating those areas in need of additional investigation. Comparison is made between the spin glasses and the better understood "giant moment" systems in order to gain further insight into the nature of random magnetic alloys. A phenomenological model is presented to connect the various experiments, and some conjectures about the future directions of this research are offered.

Introduction
Several years ago, the concepts suggested by the terms "spin glass" and mictomagnet" first began appearing in the physics and metallurgy literature. Their use was related to the growing interest in problems of an amorphous or random nature. Also, at this time experimental progress in the Kondo alloys was waning, for it was being recognized that at low temperatures impurity-impurity interactions were interfering with the pure Kondo behavior of a single localized moment and its surrounding conduction electrons. Although in a metal the magnetic impurities interact via the conduction electrons, this RKKY interaction is an oscillatory function of the distance between the local moments which, for a random alloy, introduces a mixed coupling (parallel or antiparallel) among the moments. Thus, there can be no "periodic" or "usual" type of long range ferro- or antiferromagnetic order.

At the previous International Symposium on Amorphous Magnetism\textsuperscript{1}, some of the then controversial experiments and the forerunners of a theoretical description were presented and discussed. In the intervening three years, the proverbial literature explosion has taken

\textsuperscript{*}Invited paper.

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place with well over 50 experimental and 50 theoretical papers being published in this short time. Since the theoretical area and its latest successes are being reviewed at this Symposium\textsuperscript{2}, in the present paper we will focus our attention on some of the recent experimental progress and attempt to discuss these observations in terms of simple physical models. An earlier survey of the salient spin glass/mictomagnet properties has already appeared\textsuperscript{3}.

However, before proceeding, it should be noted that the notion of a random spin freezing at a well-defined temperature offers a powerful and very general description for a wide class of magnetic alloys. The basic ingredients of "good" moments, and a random distribution and interaction of spins are a common characteristic of many systems. For "weak" or fluctuating moments (CuFe\textsuperscript{,} PdCr\textsuperscript{5}), these can be "toughened" by a strongly magnetic local environment, i.e., simply by increasing the concentration. The exchange enhanced hosts which become giant moment ferromagnets (Pd with Mn, Fe, Co\textsuperscript{6}) when diluted with magnetic impurities, can easily be converted into spin glasses by the addition of H or Ag to reduce the high density of d-states in the Pd host\textsuperscript{7,8}. As a matter of fact any mixing of the magnetic interactions, as for example with more concentrated PdMn produces the spin glass state\textsuperscript{9}. At present many such alloy systems are now available and all show a common spin glass type of behavior. For it is almost too easy to fabricate another spin glass system, rather than to gain a deeper understanding of the basic physics involved in the archetypal CuMn and AuFe spin glass alloys. Nevertheless, some prudence is perhaps necessary when dealing with such alloys. For while one can always take extreme precautions in the melting or heat treatment of a binary alloy and then assume it to be random, there exists sufficient and hard won experimental evidence that short range or local order may sometimes be present, and this certainly can influence the magnetic ordering. So now that we are achieving a more sophisticated knowledge of these alloy systems, the fundamental metallurgy becomes a very important factor and well-characterized samples are required to fully interpret the variety of experimental measurements.

Recent Experiments
One of the most intriguing spin glass features is the sharp, well-defined freezing temperature $T_F$ which occurs in some of the measurements. Accordingly, we may divide our collection of experiments into two classes: (I) those which show a clear freezing temperature, and (II) those which exhibit a broad change of behavior over a wide temperature range, but for which no distinct value of $T_F$ may be extracted. This is a unique behavior especially when contrasted with the giant moment random alloys of similar concentration\textsuperscript{6}. For these latter systems possess an unmistakable and consistent Curie temperature (not, however, unusually sharp) from all of the different measurements, despite the fact that such alloys represent an inhomogeneous type of ferromagnet.