REMANENCE AND APPROACH TO SATURATION OF $\mathrm{Au}_{0.95}\mathrm{Fe}_{0.05}$[†]

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The purpose of this communication is to announce (1) the measurement in $\mathrm{Au}_{0.95}\mathrm{Fe}_{0.05}$ of remanence, (2) the determination of a ferromagnetic Weiss constant, (3) the measurement of magnetization in high fields where saturation effects appear, (4) the satisfactory comparison of some of the magnetization results with the recent discernment of the possible ferromagnetic or antiferromagnetic nature of alloys dilute with respect to the paramagnetic atom by means of recoilless emission,[1] or Mössbauer effect, and (5) the suggested possible limited applicability of some hypotheses about threshold concentrations of paramagnetic atoms needed to support ferromagnetic or ferrimagnetic ensembles.

Magnetization measurements have been carried out down to liquid helium temperatures and in magnetic fields up to 95 000 gauss,[2] as well as in zero magnetic fields. A sample displacement method[3] was used in which a sample is moved with respect to a coil system in series with a ballistic galvanometer. The deflection of the galvanometer is proportional to the magnetic moment of the sample. Calibration with a sample of pure nickel fixes the absolute magnitude of the magnetic moment or magnetization of the alloy under study. A spherical sample of $\mathrm{Au}_{0.95}\mathrm{Fe}_{0.05}$ weighing 18 grams was used.

Figure 1 shows a plot of magnetization against magnetic field for various temperatures. It is seen that at 295°K,

$$M = 9.17 \times 10^{-6} H, \tag{1}$$

where M is in Bohr magnetons per atom of iron. At 77.4°K the magnetization is nearly linear, especially at low fields:

$$M = 47.4 \times 10^{-6} H. \tag{2}$$

From the Curie-Weiss law,

$$\chi = M/H = C/(T - \theta), \tag{3}$$

and Eqs. (1) and (2), $\theta = +23$°K. Conventionally, when θ is zero, the material is an ideal paramagnetic; when θ is positive, ferromagnetic interaction is indicated; and if negative, an antiferromagnetic interaction is indicated. Thus on the

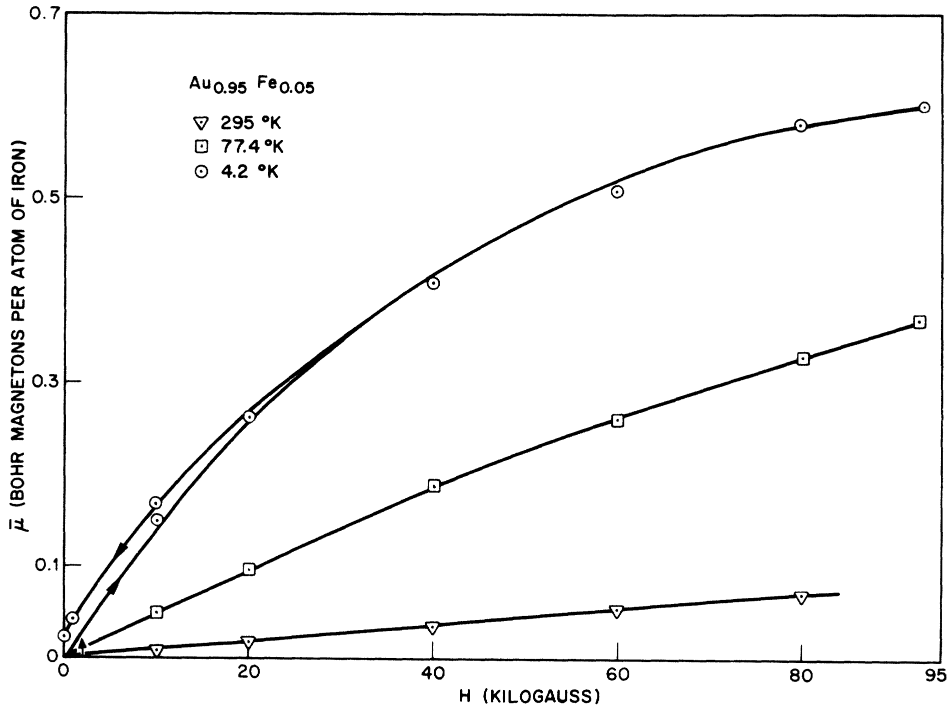

FIG. 1. Plot of Magnetization (M) against magnetic field (H) for $\mathrm{Au}_{0.95}\mathrm{Fe}_{0.05}$ at 295°K, 77.4°K, and 4.2°K.

basis of a positive Weiss constant, $Au_{0.95}Fe_{0.05}$ shows a ferromagnetic interaction.

No remanence is shown either at 295°K or at 77.4°K by this alloy. However, at liquid helium temperatures, remanence is shown and saturation effects observed. At 95 000 gauss and 4.2°K, a magnetization of 0.63 Bohr magneton per atom of iron is reached. The zero-field magnetization at this same temperature is 0.022 Bohr magneton per atom of iron. When the temperature is lowered to 1.5°K the magnetization is only slightly higher than at 4.2°K, but the zero-field magnetization is up to 0.04 Bohr magneton per atom of iron at the lower temperature. The magnetic field needed to reduce the remanence to zero is about 2000 gauss.

The magnetic ordering indicated by our measurements is in keeping with observations[1] of magnetic ordering through the measurement of the magnetic field at the iron nucleus using the Mössbauer effect. The positive Weiss constant[4] in Eq. (3) indicated by susceptibility measurements at high temperatures points to a ferromagnetic interaction. The relatively high remanence when initially cooled in zero field is further indication of ferromagnetic interaction. There is some evidence of a small amount of antiferromagnetic interaction, viz., the magnetization in the low-field (less than about 15 000 gauss) range is slightly lower at 1.5°K that at 4.2°K. This order is reversed at intermediate and high fields; the difference is still slight. Although saturation effects are observed in the liquid helium range, absolute saturation is not reached, even at 1.5°K and 95 000 gauss. This circumstance can arise partly from anisotropies and general structure effects.

Thus, the $Au_{0.95}Fe_{0.05}$ system studied here shows many indications of ferromagnetic interactions and some indicated antiferromagnetic[4] interactions at <u>restricted</u> temperatures and magnetic fields. In view of this distribution of experimental evidence, it is therefore suggested that this material be looked upon as a characteristically ferromagnetic system, or a ferrimagnetic, or a mixed ferromagnetic and antiferromagnetic (of which the spiral structure is a possible special case), or a metamagnetic[5] substance. In any case, the proof of magnetic ordering by the Mössbauer measurements[1] and by the magnetization results reported here makes it necessary to view with caution the serious application of a model[6] which arrives at threshold concentrations of the paramagnetic atom on the assumption of no indirect exchange. It makes necessary the consideration of free electrons as the intermediary for indirect exchange.[7] This work is being extended to a variety of concentrations of iron in gold.

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[2] The magnetic fields, up to 95 000 gauss, were produced in Magnet LTL-III at the Low Temperature Laboratory at the University of California, Berkeley, California.

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