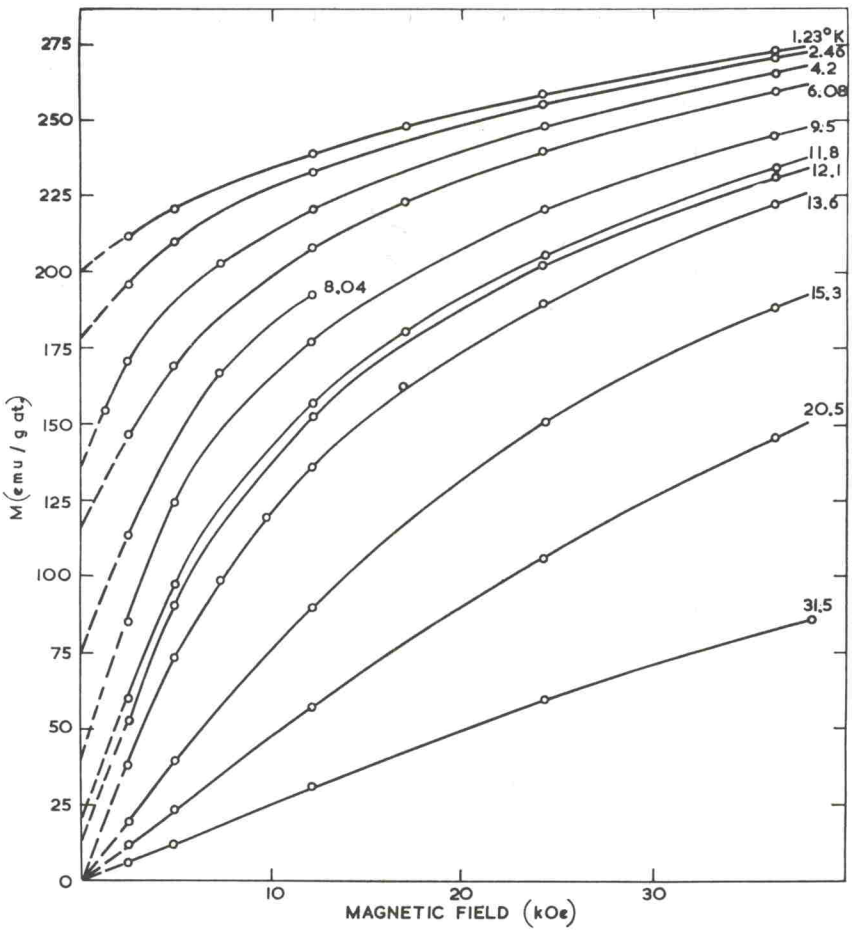


FIG. 4. Magnetization curves (corrected for the presence of 5% $Sc_2In$) for a sample of a 24.2 at. % In alloy.

the indium-rich terminal composition and therefore should have a fixed susceptibility. In fact, this was not found after correcting the observed susceptibilities for the appropriate amounts of $Sc_2In$ present in the samples.

The 21.1 at. % In sample lies in the $Sc_3In$+Sc–In solid solution phase field and the $Sc_3In$ phase in this sample should have the scandium-rich terminal composition. The susceptibility of this composition was determined by again correcting the observed results for the presence of the Sc–In solid solution.[19] The susceptibility so obtained falls between the extreme values obtained for the indium-rich terminal composition.

In order to study the possible dependence of the magnetic behavior on the degree of order of the $Sc_3In$ phase measurements were made on a sample of the 23.2 at. % In alloy which had been water quenched from 1000°C, after a 15-h anneal, and a further sample which had been subjected to a large reduction (~10:1) by rolling. It is evident from the data presented in Fig. 3 that both of these treatments appreciably decreased the susceptibility for this nominal composition. Unfortunately, the quenched sample also underwent a phase composition change with ~9% of $Sc_2In$ being precipitated as a consequence of the heat treatment (Table II). However, the decrease in the susceptibility is greater than can be accounted for simply by the formation of the $Sc_2In$, but as this increase in the amount of the $Sc_2In$ phase in the sample must result in a change in composition of the $Sc_3In$ phase we are unable to state specifically that the decrease in the susceptibility for this sample is solely associated with a change in the degree of order of the $Sc_3In$ phase.

The sample subjected to heavy cold work, on the other hand, showed no change in composition and therefore this complication does not arise and we are able to conclude that the susceptibility of the $Sc_3In$ phase is dictated by its degree of order.

### Magnetization Behavior

The magnetization measurements were mainly confined to the 24.2 at. % In sample because it had the strongest magnetic behavior. Magnetization curves in fields up to 40 kOe at temperatures from 31.5 to 1.23°K were made and the results, corrected for the presence of 5 volume % $Sc_2In$, are shown in Fig. 4. Above 35°K the magnetization curves up to 40 kOe are linear with field within the limits of experimental accuracy. Below 35°K there is an increasing departure from linear behavior suggesting that the alloy becomes ferro-

[19] In the absence of any susceptibility measurements for Sc–In solid solutions a value of $\chi = 6 \times 10^{-6}$ emu/g, based upon measurements on Sc [W. E. Gardner and J. Penfold, Phil. Mag. 11, 549 (1965)], has been assumed.

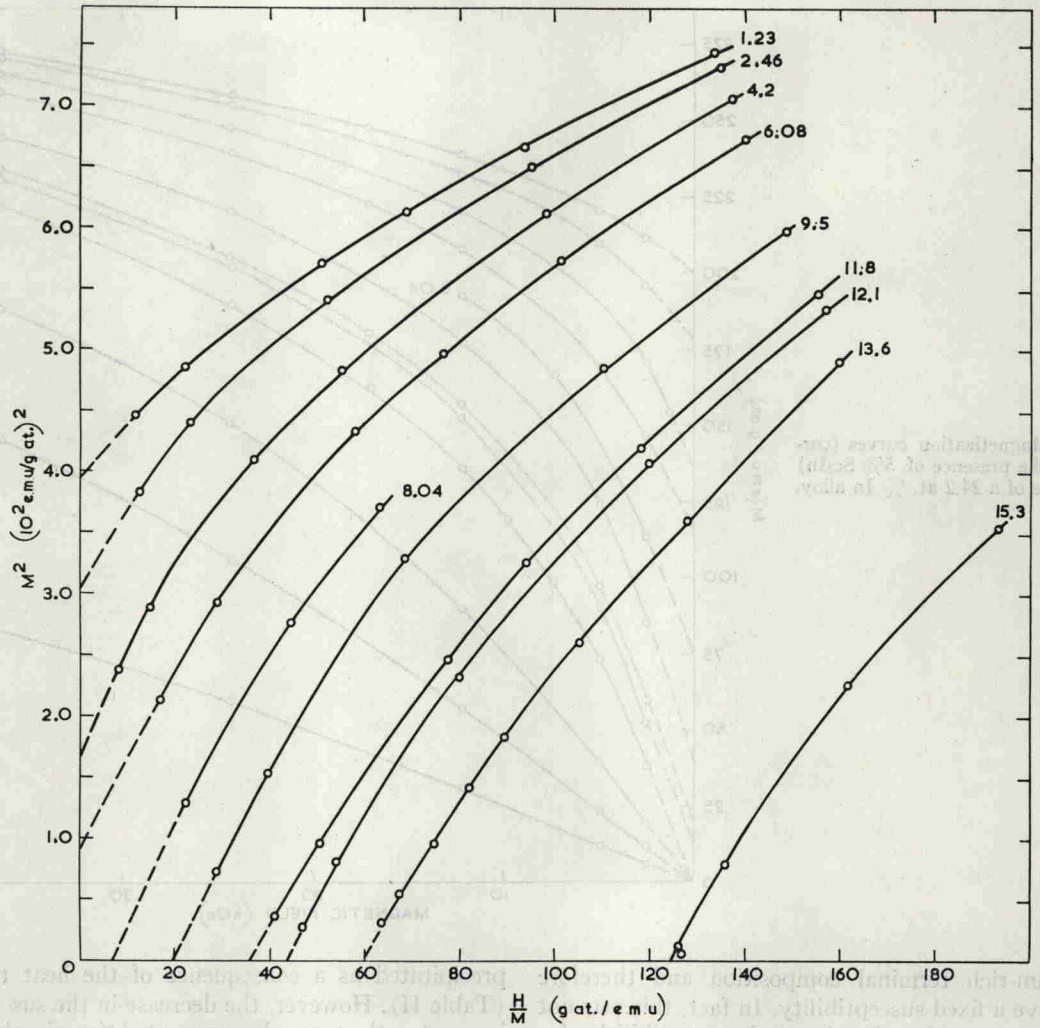


FIG. 5. Plots of $M^2$ versus $H/M$ for a sample of a 24.2 at. % In alloy.

magnetic. It is clear, however, from the curve obtained at 1.23°K that it is not possible to magnetically saturate the sample in fields up to 40 kOe. Thus, the incremental susceptibility at 40 kOe and 1.23°K ($1250\times10^{-6}$ emu/g atom or $190\times10^{-6}$ emu/g) is far higher than normal paramagnetism would produce.

The magnetization curves of the 21.1 at. % In sample also exhibited departures from linear behavior at liquid-helium temperatures. At 1.3°K the magnetization in 10 kOe was about 25% of that for the 24.2 at. % alloy at this field and temperature. However, the 26.2 at. % alloy showed only slight deviations from linearity in fields up to 13 kOe at 1.3°K with $\chi_g\sim40\times10^{-6}$ emu/g. Thus, although ferromagnetism persists in the $Sc_3In$ phase present in the 21.1 and 26.2 at. % In samples, it is considerably weaker than that in the 24.2 at. % sample.

### Determination of $T_c$

By definition, a ferromagnetic state commences with the appearance of spontaneous magnetization at a temperature known as the Curie point. It is, however, impossible to determine unambiguously the Curie point of a real ferromagnet. The following approaches are amongst those which are usually employed[20] to determine $T_c$:

(i) One is the appearance of remanence, i.e., the existence of a hysteresis loop, which is determined by magnetostatic forces.

(ii) A second is a direct application of the definition, namely attempting to determine the temperature at which the spontaneous magnetization goes to zero by means of an extrapolation to zero magnetic field of the high-field magnetization data, in order to avoid magnetocrystalline effects. Such an extrapolation is usually undertaken[21] by plotting $M^2$ versus $H/M$ at a number of temperatures above and below the Curie point and associating $T_c$ with the curve which passes through the

[20] K. P. Belov, *Magnetic Transitions* (Consultants Bureau Enterprises, Inc., New York, 1961), Chap. II.

[21] K. P. Belov and A. N. Goryaga, Fiz. Metal i Metalloved. **2**, 441 (1956); A. Arrott, Phys. Rev. **108**, 1394 (1957).