TABLE V. Comparison of the magnetic properties of Sc_3In and $ZrZn_2$.

	T_c(°K) Initial susceptibility	High field	θ (°K)	p_{eff}/(TM[a] atom)	Moment/(TM atom) (μ_B) c	10 kOe[b]	40 kOe[b]	($\partial M/\partial H$) at 2°K and 40 kOe (10^{-6} emu/g at.)
Sc_3In	6.1	7.5	16	0.67	0.2	0.055	0.066	1250
$ZrZn_2$	32[d]	17.5[e]	35[f]	0.75[f]	0.25	0.141[e]	0.191[e]	2830[e]

[a] Transition metal.
[b] Calculated from magnetization curves.
[c] Calculated from p_{eff}.
[d] Reference 8.
[e] Reference 6.
[f] Reference 5.

and the value of p_{eff} to decrease. If we assume that the moment is entirely associated with the scandium atom, the value of p_{eff} per scandium atom (Table III) is still much smaller than that corresponding to $S=\frac{1}{2}$. In fact the moment per scandium atom [obtained from the relationship $\mu=(1+p_{eff}^2)^{1/2}-1$] is only $0.20\mu_B$ (Table III), which suggests that the spin-density distribution differs considerably from a free-atom configuration and that the $1/T$ dependence is associated with the band structure. It follows, therefore, that the susceptibility data would be better interpreted with Eq. (2).

Since we have shown that the susceptibility depends critically on the heat and mechanical treatment that a sample has received, it is evident that the spin-density distribution at a scandium atom is sensitive to its location and may even possibly fall to zero when the scandium occupies an indium site.[31]

Now it might be considered extremely fortuitous that the band structure of Sc_3In is such that $\chi_c(T)$ is inversely proportional to T, and that a more reasonable possibility, retaining the localized model, would be that the low moment is due to an averaging process over scandium sites having an *integral* moment and zero moment. However, in view of the fact that the 24.2 at. % In showed full ordering, within the limits of the resolution associated with the x-ray determination, it would seem impossible that a sufficient number of inequivalent sites exist so as to account for so small a moment. We therefore reject the localized model and conclude that the band structure of ordered Sc_3In is indeed such as to produce the observed susceptibility behavior.

Magnetization below T_c

Plots of H/M versus M^2 are normally associated with ferromagnets exhibiting localized behavior, but they are equally appropriate for a band ferromagnet where the Fermi energy occurs in the middle of a parabolic peak in a $1/N(E)$-versus-n plot, where n is the total number of electrons and $N(E)$ is the density of states.[28] As discussed above in the determination of T_c from high-field magnetization measurements, plots of H/M versus M^2 do not yield straight lines for the Sc_3In phase. Moreover, we have not been able to find any simple function which will represent the magnetization data, and thus it has not been possible to obtain the spontaneous magnetization as a function of temperature. Furthermore, as the magnetization curves are strongly field-dependent up to 40 kOe at low temperatures, it has not been possible to obtain a saturation moment for the Sc_3In phase.[32] However, smoothed values of the magnetic moment, assumed to be entirely associated with the scandium atoms, are given in Table IV at 10-kOe intervals for three temperatures. These values may be compared with the 10% lower value of $0.051\mu_B$/(Sc atom) at 1.4°K in 14 kOe given by Matthias *et al.*[3] We attach no significance to this difference due to the sensitivity of the magnetization of the Sc_3In phase to heat treatment. It should be noted that the moment per Sc atom obtained from the high field measurements is only about $\frac{1}{3}$ of the value deduced from the susceptibility results (Table III), which adds further support to our contention that the magnetic behavior is best described in terms of the band model.

Values of instantaneous susceptibility at a number of fields at 1.2°K are also given in Table IV. The value of $\partial M/\partial H$ at 1.2°K and 40 kOe, 1200×10^{-6} emu/g at. is much larger than the susceptibility obtained for pure scandium at this temperature, namely 300×10^{-6} emu/g at.

A remarkable similarity exists between the magnetic properties of $ZrZn_2$ and those of the Sc_3In phase. This is illustrated in Table V where a direct comparison of the values of θ, p_{eff}, and the moment expressed per transition metal atom is given.

Variation of T_c with Pressure

The present theoretical understanding of exchange forces provides no *a priori* guidance as to the magnitude or even the sign of the expected pressure dependence

[31] The same model may be equally appropriate for $ZrZn_2$ since the susceptibility of this compound has also been observed to vary from sample to sample (Ref. 6).

[32] The failure of magnetization curves to saturate at high fields and low temperatures has been interpreted as evidence for nonlocalized magnetic behavior (Ref. 6). However, very dilute alloys (~0.02 at.%) of Mn in Cu [J. A. Careaga, B. Dreyfus, R. Tournier, and L. Weil, in *Proceedings of the Tenth International Low-Temperature Conference, Moscow, 1966* (Proizvodstrenno-Izdatel'skii Kombinat, VINITI, Moscow, USSR, 1967)]; and dilute alloys (~1 at. %) of Gd in yttrium [W. E. Gardner and H. J. Williams, in *Proceedings of the Tenth International Low-Temperature Conference, Moscow, 1966* (Proizvodstrenno-Izdatel'skii Kombinat, VINITI, Moscow, USSR, 1967)], systems which closely adhere to the concept of localized moments, also fail to saturate under similar conditions.

TABLE VI. Comparison of $\partial T_c/\partial P$ for the Sc_3In phase with values for other ferromagnets.

Element or alloy	$\partial T_c/\partial P$ (10^{-3} °K bar^{-1})	T_c (°K)	$\frac{\partial \ln T_c}{\partial \ln V}$	K[a] (10^{-7} bar^{-1})
Fe[b]	0 ± 0.1	1036	0	5.9_4
Co[b]	0 ± 0.1	1404	0	5.2_8
Ni[b]	0.35 ± 0.02	624	-1.0_5	5.3_5
Gd[c]	-1.63 ± 0.07	293	2.1_3	26.1
Tb[c]	-1.08 ± 0.03	228	1.8_9	25.1
Dy[d]	-1.24 ± 0.1	174	2.7_4	26.0
$Fe_{0.7}Ni_{0.3}$[b]	-5.8 ± 0.2	372	$26._3$	5.9_4[f]
$Ni_{0.68}Fe_{0.32}$[b]	-0.1 ± 0.1	885	0.2_1	5.3_5[g]
Au_4Mn[e]	2.7 ± 0.3	333	$-14._1$	5.7_7[h]
Sc_3In	$0.19_5\pm0.01$	6.1	$-13._9$	23.0[i]

[a] Values from K. A. Gschneidner Jr. Solid State Phys. **16**, 275 (1964).
[b] Reference 22.
[c] Reference 23.
[d] J. E. Milton and T. A. Scott, Phys. Rev. (to be published).
[e] T. Hirone, T. Kaneko, and K. Kondo, in *Physics of Solids at High Pressures*, edited by C. T. Tomizuka and R. M. Emrick (Academic Press Inc., New York, 1965), p. 298.
[f] Value for iron.
[g] Value for nickel.
[h] Value for gold.
[i] Value for scandium, C. E. Montfort and C. A. Swenson, J. Phys. Chem. Solids **26**, 623 (1965).

of magnetic transitions. The greater part of the effort expended[23,33] in the study of the pressure dependence of magnetic transitions has been directed towards the rare-earth materials and their alloys, in which the magnetic interaction is of an indirect nature. For these materials it has been observed that T_c decreases with pressure. No such single sign has been observed for the transition metals and their alloys.

In Table VI we compare the values of $\partial T_c/\partial P$ and the dimensionless quantity $\partial \ln T_c/\partial \ln V$ for the Sc_3In phase with values previously reported for some other ferromagnets. It would appear that the magnitude and sign of the observed pressure dependence for the Sc_3In phase cannot be considered to differ from those observed for other ferromagnetic materials.

[33] D. Bloch and R. Pauthenet, in *Proceedings of the International Conference in Magnetism, Nottingham 1964* (The Institute of Physics and The Physical Society, London, 1964), p. 255; L. B. Robinson, S. I. Tan, and K. F. Sterrett, Phys. Rev. **141**, 548 (1966); K. P. Belov, S. A. Nikitin, and A. V. Ped'ko, Zh. Eksperim. i Teor. Fiz. **45**, 26 (1963) [English transl.: Soviet Phys.—JETP **18**, 20 (1964)]; I. G. Austin and P. K. Mishra, Phil. Mag. **15**, 529 (1967).

CONCLUSION

(i) The Sc_3In phase field exists over a narrow range of composition (approximately 22–23 at. % In at 400°C).

(ii) The magnetic susceptibility of this phase depends critically on the degree of order and is considerably reduced by disordering.

(iii) The inverse of the corrected susceptibility is proportional to temperature between 50 and 250°K, but since the slope corresponds to a moment of $\sim 0.2\mu_B/$(Sc atom), it is felt that this behavior is a consequence of a fortuitous energy band shape at the Fermi surface.

(iv) The magnetization of the Sc_3In phase shows no evidence of saturation in fields up to 40 kOe at 1.2°K. The maximum moment achieved per scandium atom was $0.066\mu_B$, which is considerably smaller than that deduced from the susceptibility by assuming it follows a Curie-Weiss relationship.

(v) The initial susceptibility curve contains structure at temperatures below 6.1°K (the low-field Curie temperature). It is suggested that this may be due to the presence at T_c of appreciable temperature-dependent magnetocrystalline anisotropy.

(vi) The structure in the initial susceptibility curve is unaffected by pressures up to 6 kbar, but cannot be resolved at 13.6 kbar. The Curie temperature increases with pressure with $\partial T_c/\partial P = (0.19_5\pm0.01)\times10^{-3}$ °K bar^{-1}.

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