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THE ESTIMATION OF CORRELATION EFFECTS IN TRANSITION METALS AND ALLOYS FROM PRESSURE AND RELATED EXPERIMENTS *

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The ratio of I/I_b, where I and I_b, respectively, are the effective and bare interactions between the itinerant electrons, was estimated on the basis of high pressure and related experiments to be generally greater than 1/2 for Ni_3Ga, Ni-Rh, Invar and $ZrZn_2$, indicating weak correlation effects for these materials.

Several magnetic properties of transition metals related to volume changes have recently been considered, such as forced magnetostriction, anomalous thermal expansion, and the pressure dependencies of the susceptibility, Curie temperature (T_c), saturation magnetization (M_s), and the spin wave energy. The effects may be described in terms of a magnetoelastic coupling constant C which is particularly relevant for strongly paramagnetic (PM) and weakly ferromagnetic substances. The value of C was shown [1] to be given, to a good approximation, by the volume dependence of the parameter $\bar{I} = I\,N(\epsilon_F)$, where I is the effective interaction between the itinerant electrons and $N(\epsilon_F)$ is the density of states at the Fermi energy. Shiga [2] later calculated essentially C on the basis of Kanamori's theory [3] of correlation effects, but only for one specific material (Invar). This procedure may, however, be inverted and correlation effects may thus be assessed from high pressure and related experiments.

In the low density limit, to which the materials mentioned below approximate well, Kanamori's result [3] is approximately

$$I = I_b\,(1 + \gamma I_b/W)^{-1}\ , \qquad (1)$$

where I_b is the bare interaction, W the band width, and γ a constant [2]. In addition, $N(\epsilon_F)$ can be written as $N(\epsilon_F) = \beta/W$, where β is another constant [2]. It is implied that W and thus $N(\epsilon_F)$ scale uniformly (uniform scaling assumption) under volume changes, and Heine's result [4] $\partial \ln W/\partial \ln V = -5/3$ can be used to give

$$\partial \ln \bar{I}/\partial \ln V = (5/3)\ (I/I_b)\ , \qquad (2)$$

independent of β and γ and where I_b is assumed independent of volume.

We can define a pseudo "Grüneisen" constant $\Gamma = \partial \ln T_c/\partial \ln V$. Then from the previous theoretical result [1, 5, 6] $T_c^2 = T_F^2\ (\bar{I} - 1)$, where T_F is the effective degeneracy temperature, we have to a good approximation using (2)

$$\Gamma = (5/6)\ (I/I_b)\ (T_F/T_c)^2\ , \qquad (3)$$

where for weak itinerant electron ferromagnets $\bar{I} \approx 1$ and $T_F \gg T_c$. It can also be easily shown, using previous results [5, 6], that $\Gamma = \partial \ln M_s/\partial \ln V$.

From the above work we see that Γ is expressed in terms of the Stoner enhancement factor $S = |1 - \bar{I}|^{-1}$. In fig. 1 we give values of I/I_b as a function of S^{-1} for a few materials. For Ni_3Ga, Fawcett et al. [7] obtained the volume dependence of the PM susceptibility χ from forced magnetostriction data while S was estimated from χ and the specific heat, giving $I/I_b = 0.84$ and $S = 30$. Fawcett et al. [8] also measured the magnetostriction for thee Ni-Rh alloys near the critical concentration obtaining the values $S = 11$, 20 and 30; the corresponding values of I/I_b are independent of S. For Invar alloys Cochrane and Graham [9] measured $\Gamma = \partial \ln M_s/\partial \ln V$. Using these values of Γ and the previously estimated values for T_F [6], along with the experimental

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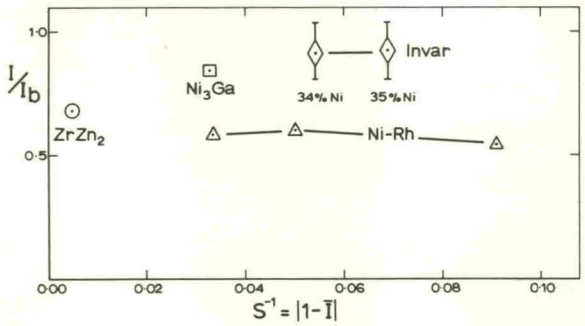

Fig. 1. I/I_b values for the materials shown as specified by the values of S^{-1}.

values for T_c [10] and (3), we obtain the results shown in fig. 1. It is noteworthy to point out that the measurements of $\partial \ln M_s/\partial \ln V$ [9] agree quite well with the measurements of $\partial \ln T_c/\partial \ln V$ [10]. Finally for $ZrZn_2$, $\partial T_c/\partial p$ was predicted [1] and the measured [11] to be close to -2.0°K/kbar. The compressibility κ has been measured at Sandia by Morosin to be 11.2×10^{-4}/kbar. Hence $\Gamma = -(1/\kappa T_c)\, \partial T_c/\partial p = 83.0$ and so from earlier work [5] $I/I_b = 0.69$, $S^{-1} = 0.004$.

We interpret the results shown in fig. 1 as follows. For the materials shown, $I/I_b \gtrsim 0.5$, implying a weak correlation effect [12]. Over a limited concentration range it is reasonable to assume that I_b, as well as I in the weak correlation limit, is independent of the alloy concentration. It is therefore consistent that the values of I/I_b for the Ni-Rh and the Invar alloys are independent of $\bar{I}-1$. We also conclude that the uniform scaling assumption is reasonable for the materials discussed above.

We have applied the analysis given in this paper to Fawcett's data [13] on Pd and Pd-Rh alloys and obtained an anomalous variation of I/I_b with S^{-1}. The cause of this anomalous behaviour may be due to the breaking down of the uniform scaling assumption for Pd due to an s-d overlap, or the anomalous behaviour may be due to the orbital susceptibility being strongly volume dependent for these alloys [14].

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