Comment on "Investigation of the Magnitude and Range of the Ruderman-Kittel Interaction in $SmRh_4B_4$ and $ErRh_4B_4$"

In the Letter[1] of the above title the authors have analyzed the dependence of the magnetic transition temperatures T_M on the electron mean free path of the radiation-damaged ternary compounds $SmRh_4B_4$ and $ErRh_4B_4$ by means of an expression obtained from a modification of the Ruderman-Kittel-Kasuya-Yosida interaction.[2] This is

$$T_m \approx (g-1)^2 J(J+1) I^2 \sum_r \chi(r) \cos(\mathbf{g}\cdot\mathbf{r}), \quad (1)$$

where g is the Landé factor, J is the total angular-momentum quantum number of the rare earth, and I is the s-f exchange interaction. The sum is taken over lattice sites (excluding $r=0$) and

$$\chi(r) = \chi_0(r) \exp(-r/l), \quad (2)$$

where l is the electronic mean free path and $\chi_0(r)$ is the well-known[2] oscillatory function

$$\chi_0(r) = (x\cos x - \sin x)/x^4, \quad (3)$$

with $x = 2k_F r$, k_F being the radius of the Fermi sphere. $\chi_0(r)$ is the value of the nonlocal conduction-electron susceptibility for free electrons with an infinite mean free path. The authors of Ref. 1 take account of the effect of finite mean free path produced by radiation damage upon the nonlocal susceptibility by multiplying $\chi_0(r)$ by the factor $\exp(-r/l)$ as in Eq. (2). They justify this on the basis of a result claimed to exist in a paper of de Gennes.[3]

However, in the paper referred to,[3] de Gennes states explicitly that Eq. (2), while intuitive, was not correct, as it violated the relation

$$\chi_P = \int \chi(r)\, dr, \quad (4)$$

where χ_P is the Pauli susceptibility. This quantity is not expected to be affected by weak disorder and therefore Eqs. (1)—(2) are not valid for finite l. The point has been made before by de Châtel[4] who has shown how the range of the indirect exchange interaction can be much longer than the electronic mean free path.

Another deficiency in the use of Eqs. (1)—(3) by the authors of Ref. 1 is that they assume values of $\mathbf{q}$ appropriate for the magnetic order observed experimentally in $SmRh_4B_4$ (antiferromagnetism) and $ErRh_4B_4$ (ferromagnetism). However, the correct procedure[5] for applying Eq. (1) is to vary $\mathbf{q}$ until the maximum value of T_{max} at $\mathbf{q}_{max}$ is obtained. The material described by the model is then predicted to order magnetically at a temperature T_{max} in the mode described by $\mathbf{q}_{max}$. Equation (1) therefore predicts that $SmRh_4B_4$ and $ErRh_4B_4$ must order magnetically in the same way (for the same value of k_F which the authors of Ref. 1 assume). But this is in disagreement with experiment.

For the two reasons given above, Eq. (1) is intrinsically incapable of simultaneously describing the magnetic properties of the two ternaries, and because of this the analysis carried out by the authors of Ref. 1 must be considered questionable. Doubts about the usefulness of such free-electron calculations were raised long ago[6]; more realistic methods of calculation are now being used.[7]

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