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Microscopic Study of Kondo Effect and Electron Phonon Interaction in Heavy Fermion Systems

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ABSTRACT

We have described a Hamiltonian model that prompts two semi-molecule groups. In each of the two semi-molecule groups, as required by the test perceptions, the BCS type superconducting blending instrument is presented. The SC hole amplitudes in two separate groups are deviated from the self-reliable plots as for the Fermi level as opposed to the comparable hole estimates on either side of the Fermi level as anticipated by BCS and BCS as components. In the current case, the lopsidedness in the hole estimates is processed and it is found to be managed by the f-level situation. The superconducting (SC) hole in the upper band is enhanced more than that of the lower band at the point when the f-level position moves where the Fermi level counts. Due to the presence of the localised f-level in the lower band, the SC hole is restricted. It is also seen that the more grounded the hybridization is between the f-electrons and the conduction electrons, the smaller the two holes become. Each band's SC hole estimation is only enhanced by the SC coupling of its own band. Total SC gap for two quasi particle bands in present case is compared to the total gap As derived from the calculation of the BCS, found in symmetric gaps. The impact of the parameters of the model the position f-level and hybridization on SC holes is examined and detailed.

1. Introduction

Electronic structure of Rare-earth metals

The arrangement of rare earth metals is comparable to the topping of the 4f electronic shells from 0 to 14 on a regular basis, whereas the low outer 6s and 5d shells contain two and one electron separately. There are three conduction electrons (or a valence of 3) for the typical rare earth metals and a magnetic second equivalent to that of trivalent particles. The configuration of such a ordinary rare earth metal is $4f^n5d^16s^2(0<n<14)$ (with an N value integral). The six heavy rare-earth metals (Gd, Tb, Dy, Ho, Er and Tm) that are trivalent have an ionic magnetic second compared to the ionic magnetic second. $4f^n$ configuration and present various magnetic orderings.

Electronic properties of heavy fermion materials

Several people from the collection of heavy fermion materials become superconducting under a basic temperature The superconductivity is flying At high temperatures, heavy fermion mixes carry on like ordinary metals and the electrons can be portrayed as a Fermi gas in which the electrons are thought to be flying At high temperatures, heavy fermion mixes carry on like ordinary metals.

The Kondo effect and Kondo Lattice

The problem of antiferromagnetic interactions between f-electrons and fermion ocean can be treated as a problem of magnetic debasement in metals, with pollution occurring occasionally in the f electrons. The clarification provided by J Kondo 1964 is a huge development in the theory of magnetic pollutants

Plot of Kondo effect and Kondo lattice model

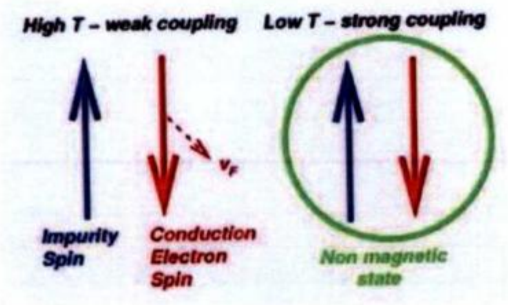

Fig. 1. The Schematic illustration of the Kondo effect.

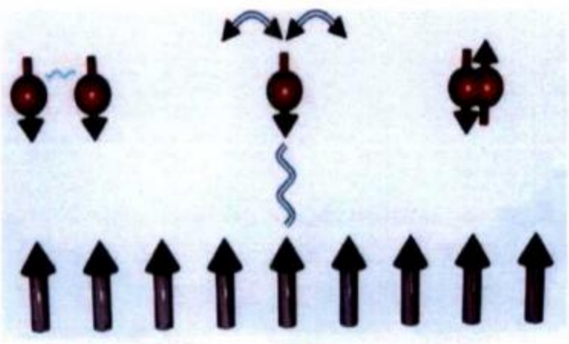

Fig. 2 The Kondo lattice model.

In the lower column (dark), the conduction electrons are depicted and the localised electrons are depicted as jolt bolts in the upper line (red), heavy fermion mixes are an unpredictable problem where a huge powerful mass m appears due to the moderate movement of the localised f-electrons by hybridization with the electrons of light conduction. This mass amplification is suggestive of the Kondo effect observed in a typical non-magnetic host for a solitary magnetic pollutant. A solid coupling occurs under a trademark temperature called Kondo temperature T_k, leading to the disappearance of the attraction (Fig . 1 and Fig2.). For nj ~ 1, local magnetic seconds are expected to be linked to turn S^{f}, which is linked to the conduction electron turn S^c through a trade interaction J_k and the trade term is given by

$$H_{hybridization} = -J_K \vec{s^c} \ \vec{S^f} \qquad (1.1)$$

T_k is defined as J_k and the thickness of conduction electron conditions $\rho\{\varepsilon_F)$ at Fermi level as

$$T_K = \frac{1}{\rho(\epsilon_F)} \exp(-\frac{1}{J_K \rho(\epsilon_F)}) \qquad (1.2)$$

The negative J_k estimate is identified moderately to the Fermi level and its width with the position of the f-level Δ_0 As the link indicates, when the potential of Coulomb goes to endlessness on the spot,

$$\rho(\epsilon_F) J_K = \frac{\Delta_0}{E_0} \qquad (1.3)$$

At low temperatures, a Fermi liquid behaviour replaces the temperature Curie paramagnetic behaviour $\text{As } T \rightarrow 0K,$ the specific heat and the susceptibility vary as $\gamma = \frac{C}{T} = \frac{1}{T_K}$ and $\chi \simeq \frac{1}{T_K}$ In Kondo problem, the spin $S^f = ½$ of the localized 4f electron corresponding to the *$4f^1$ (in Ce, j=5/2) or $4f^{13}$ (in Yb, j=7/2)* The setup is fully screened by the spin at very low temperatures. *$S^c=1/2$* Conduction electrons There is a rivalry between the Kondo effect and the Kondo effect 's magnetic arise request Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction $-J_H S_i^f \ S_{i+\delta}^f$ This was well described by the Domach diagram between rare-earth atoms at various lattice sites,

The Doniach diagram

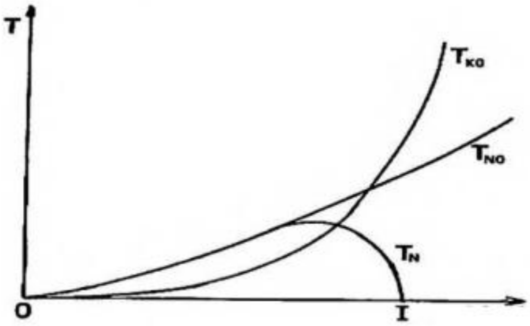

Figure 3 The Doniach diagram

The diagram shown in Fig, gives the variation of the ordering temperature and the Kondo temperature with increasing J_k "The resulting ordering lattice temperature expands at first with the expansion of $J_k\rho$, at that point goes through a most extreme and usually zero at a basic value $J_k\rho$, called a" quantum basic point "(QCP) Such a behaviour of Tn was tentatively seen with the expansion of pressure m numerous cerium mixes, for example, $CeAl_2$ or $CeRh_2Si_2$ A similar effect has been observed in

$YbCu_2Si_2$ Or again in other Ytterbium mixes, where at a given weight the temperature of the Neel starts from zero and increases rapidly with the pressure, because the pressure in the Ytterbium mixes has an opposite effect than Cerium mixes. $J_K\rho$ Cerium mixes with a little heavy fermion character and moderately small requesting temperatures are magnetically requested short of what I of QCP, usually of request 5, l0JsT For $J_K\rho$ The Cerium mixes are non-magnetic and, with a 7 usually 1J/{mol-K2) request, can have exceptionally large heavy fermion character values greater than QCP.

Heat Capacity

The specific heat C for normal metals at low temperatures consists of two terms, 1 e, (1) electronic specific heat C_{el} ' T, which is directly related to temperature, and (11) corresponds to the 3D temperature square, the lattice commitment to explicit warmth.

$$C = C_{el} + C_{ph} = \gamma T + \beta T^3 \qquad (1.4)$$

with proportionality constants γ 1 and (H The direct term is predominant at low temperature, and the steady γ 1 Therefore, in this straight electron term, explicit warmth can be a decent marker of strong electron mass relative to the viable electron mass m * The HF compounds $CeAl_3$ has a γ around $1620mJ/molK^2$, $CeCu_2Si_2$ around $1100mJ/molK^2$, $CeCu_6$ around $1600mJ/molK^2$, UPt_3 around $420mJ/molK^2$ etc The electronic engagement is the important part of the specific warmth for the free-electron gas in the referenced temperature range, (without connection) the electronic explicit warmth is given by the electronic warmth.

$$C_{el} = \gamma T = \frac{\pi^2}{2}\frac{Nk_B^2 T}{\epsilon_F} \qquad (1.5)$$

With Boltzmann 's factor kp, the proportionality constant γ is referred to as the Sommer field parameter, the total electron system N and Fermi energy ε_F (the highest single particle energy of the electronic states occupied).

Relation between heat capacity and thermal effective mass

The Fermi energy ε_F is inversely proportional to the particle's mass m * for electron gas with a quadratic dispersion relationship.

$$\epsilon_F = \frac{\hbar^2 k_F^2}{2m^*} \qquad (1.6)$$

Since the Sommerfeld parameter where k_F stands for the Fermi wave number, the effective mass relies on the electron density γ 1 is inversely proportional to ϵ_F, γ is proportional to the particle's effective mass For high values of γ 1, The metal acts as a free electron gas that has conduction electrons with a high thermal effective mass.

Heat capacity for UBe_{13} at low temperatures

UBe_{13} shows a peak at a temperature around 0.76 K that goes down to zero with a high slope when the temperature approaches 0K Because of this peak, the γ-factor is much higher in this temperature range than for the free-electron gas In contrast, above 0K, the specific heat for this heavy fermion compound approaches the expectation for this heavy fermion compound.

Electronic specific heat some of the HF systems

The experimental results of electronic specific heat $C(T)$ (in $C(T)/T = \gamma + \beta T^2$) and electrical resistivity $\rho(T)$ (in $\rho(T) \simeq \rho(O) + BT^2$) of many heavy fermion systems ($CePd_3$, $CeAl_{13}$ etc) at low temperatures show anomalous behaviour just like anomalous behaviour of magnetic susceptibility at low T The low temperature electronic specific heats C(T) of systems like $CeAl_{13}$, $CeCu_6$ etc, show an enormous enhancement of the specific heat coefficients $\gamma(T) \simeq C(T)/T$, suggesting a very heavy effective mass of Fermi liquid state The temperature dependence of $\gamma(T)$ of these compounds show a peak (with γ_{max}) at a relative low temperature, and $\rho(T)$ 1 increases with increasing temperature i

These systems show a type of cross-over from low-T coherent Fermi-liquid behaviour to the high-71 dense Kondo behaviour. It has been suggested that the low-temperature coherent Fermi liquid phase is very well represented by the periodic Anderson model (PAM), where the coherent hybridization on all N sites between conduction states and f-states is considered. The appearance of a possible pseudo gap near Fermi energy has been attributed to the cause of the anomalous low-temperature behaviour of these systems due to coherent hybridization. However, it is not clear how, at high temperatures, heavy fermion systems act like a collection of independent magnetic ions and start acting as a coherent Fermi liquid at very low temperatures.

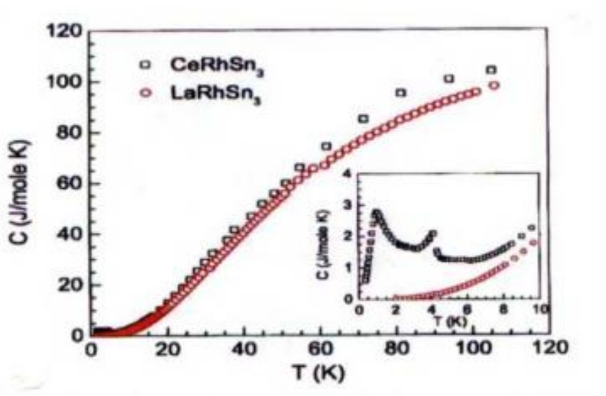

Fig. 4 The temperature dependence of the zero magnetic field specific heat of CeRhSns and LaRhSn3 measured in the temperature range 0.35 — 105K. The Inset shows view of low temperature specific heat below 10K.

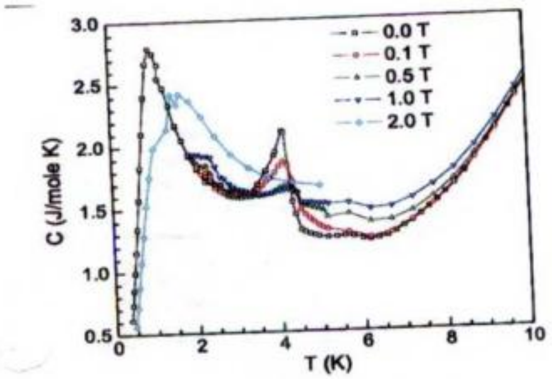

Fig. 5 The low temperature specific heat of CeRhSn3 measured under application of different magnetic fields ranging from 0 to 2T.

In the special low temperature heat, a transition around 1 K (inset of Fig .. 5) is observed, corroborating the transition found in the susceptibility as well. Under the application of magnetic fields specific heat is measured in order to investigate the nature of this transition. At 4 K, the specific heat peak has a rather weak shift in temperature. The jump in specific heat is quickly suppressed with an increase in magnetic field strength. The anomaly at K, on the other hand, shows a marked shift to the higher temperature side, e.g. the transition temperature for a field of 2 T moves to ~ 1.5 K. Such a type of field dependence on the transition temperature may indicate in the specific heat data that CeRhSn3 undergoes a ferric-to ferromagnetic transition at K. With applied fields, the ordering temperature of a Ferro magnet increase, while it typically decreases for an antiferromagnet with applied fields.

2. Objectives of the study

1. To study on Hamiltonian model that prompts two semi-molecule groups.
2. To study on Electronic structure of Rare-earth metals Electronic properties of heavy fermions materials

3. Conclusion

The mean field parameters are self-consistently solved depending on temperature, i.e. the Kondo singlet A and the nearest neighbour f-electron correlation F, and their interaction is studied. Both parameters illustrate the mean-field behaviour. Similarly, the temperature at which the parameter of correlation F is zero is referred to as the temperature of correlation phase of their coexistence is characterised by non-zero values of the parameters of the mean field. The Kondo temperature is defined as the temperature at which Kondo Conclusion 159 Singlet A disappears. The consequence of increasing the Kondo coupling is that the Kondo singlet formation is significantly improved, but at the coexistence phase of low temperatures, the magnetic correlations are suppressed. The critical temperatures for the two order parameters are separate. The magnetic correlations are enhanced near the magnetic transition temperature when the direct Heisenberg interaction between the nearest neighbour localised spins is strong, while the Kondo singlet formation is enhanced in the coexistence phase. This is consistent with some of the Ce compounds' experimental findings The correlations are improved near the magnetic transition temperature when the direct Heisenberg interaction between the nearest neighbour localised spins is strong, while the formation of the Kondo singlet is improved in the coexistence phase. Our findings show that at the Kondo temperature Tk, at the Tc or correlation temperature, the electron specific heat exhibits one sharp maximum and another flat maximum. Similar sharp peaks are also observed in entropy's temperature dependence. Both sharp peaks shift their positions when the f-level position is altered with respect to the Fermi level , indicating the strong interaction between the Kondo interaction and the correlation. It is observed that the Kondo coupling increases the correlation temperature more strongly than the Kondo temperature. The increase in the correlation coupling suppresses the Kondo temperature and magnitude of the Kondo singlet more strongly than the correlation parameter. Our mean-field calculation renormalizes the f-level positions as well as the hybridization between the f-electrons and the conduction electrons. We thus observe changes in the density of states of the conduction band (DOS) as well as in the efficient f-electron band.

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