Nernst effect and Kondo scattering in (CeLa)Cu$_2$Si$_2$

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(IOP-CAS, from April 2012)

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Outline

1. Introduction to magneto-thermoelectric transport of HF systems.
2. Nernst effect as a probe of relaxation time spectra and its relation to thermoelectric power.
3. Experimental results on (CeLa)Cu2Si2 and discussion.
4. Summary.
Introduction

Archetype TEP of Kondo systems

Gradually adding Ce (or Yb) to a nonmagnetic matrix, the TEP responses following certain rules, independent of the carrier type in the matrix.

Open issues: microscopic reason for the different type of TEP(T); why carrier type of the nonmagnetic matrix not important...
TE transport tensor in field

Thermoelectric power (diagonal $S_{xx}$)

$$S = \frac{E_x}{|\Delta T|}$$

*Origin: p/h asymmetric DOS and $\tau$*

Nernst coefficient (off diagonal $S_{xy}$)

$$\nu = \frac{-E_y}{B_z} \left( \frac{\partial T}{\partial x} \right)$$

$$= \frac{E_y}{B_z} |\Delta T|$$

*Origin: p/h asymmetric $\tau$, band and scattering anisotropy, vortex dynamics...*
Important Assumptions:
1. Relaxation time approximation
2. Relaxation time is the only E-dependent term in the Hall angle
3. Measurements in low magnetic field

Interplay between diagonal and offdiagonal TE component

Thermopower:

\[
S_{xx} = -\frac{\pi^2}{3} \frac{k_B^2 T}{e} \frac{\partial \ln \sigma_{xx}}{\partial \varepsilon_F}
\]

Nernst:

\[
S_{xy} = -\frac{\pi^2}{3} \frac{k_B^2 T}{e} \frac{\partial \tan \theta_H}{\partial \varepsilon_F} \quad \text{(Hall angle } \tan \theta_H = \frac{\sigma_{xy}}{\sigma_{xx}})\]

In principle, Nernst measurement can disentangle the different sources of thermopower.

\[
S(T) = \frac{\pi^2}{3} \frac{k_B^2 T}{e} \left[ \frac{\partial \ln \sigma}{\partial \varepsilon} \right]_{\varepsilon = \varepsilon_F}
\]

\[
= \frac{\pi^2}{3} \frac{k_B^2 T}{e} \left[ \frac{\partial \ln \tau}{\partial \varepsilon} + \frac{\partial \ln D}{\partial \varepsilon} \right]_{\varepsilon = \varepsilon_F}
\]

\[
S(T) = -\frac{\nu}{\mu_H} + \frac{\pi^2}{3} \frac{k_B^2 T}{e} \left[ \frac{\partial \ln D}{\partial \varepsilon} \right]_{\varepsilon = \varepsilon_F}
\]
Several orders of magnitude different for gold of presumably different quality!

→ Strong indication of Kondo scattering in Fletcher’s results (dirty Au).

→ Much more sensitive to unconventional scattering process than thermopower.
Resistivity of (CeLa)Cu2Si2

\[ \rho(T, x) \]

\[ \rho = \text{Resistivity} \]

\[ T = \text{Temperature} \]

\[ x = 0.5: \text{crossover from coherent to incoherent conduction} \]

Interested: how Nernst signal evolves when coherence set in, where Kondo scattering is suppressed?
Also interested: does the very different low temperature (< 100K) thermopower of lattice (Ce1.00) and impurity (Ce0.02, Ce0.09) Kondo system indicate that the former is asymmetric –DOS driven, and the latter one is asymmetric-scattering-driven (coherency as the control parameter).
Nernst coefficients

1. Nernst of LaCu2Si2 much smaller than Ce-based systems
2. Common feature for Ce compounds: high-T negative peak

Nernst effect in CeCu$_2$Si$_2$

A-S Rüetschi, K Sengupta, G Seyfarth and D Jaccard
Nernst and thermopower: LaCu$_2$Si$_2$

Thermopower dominated by DOS.
Nernst signal dominated by scattering.
→ S and Nernst coefficient are largely independent.
LaCu2Si2: approach from ac.ph. scattering

- Canonical resistivity and mobility
- Electron scattered by acoustic phonons

\[ \mu_H \sim T^{-1} \]

Inputs:

- Acoustic phonon scattering:
  \[ \tau = \tau_0 \varepsilon^{\frac{-1}{2}} \]

Bare electron mass
Thermopower can be well traced by Nernst signal.

Asymmetric scattering rate (rather than f derived heavy band) leads to large S in the whole T range (2K -250K).

No clear evidence of heavy-band formation down to 2 K.
Ce0.09- and Ce0.02-compounds

Surprise: Thermopower of Ce0.09 and Ce0.02 cannot be well reproduced by using Nernst signal?
Measured thermopower vs. anticipation from scattering term

Agreement worsens as Ce concentration decrease.

Assuming validity of exponent law leads to extremely large exponent \( r \! \)!
$R_H$ (normalized by Ce concentration) increases with decreasing Ce concentration. 

Useful hint for understanding the anomalous Nernst effect, especially in the low Ce concentration side.
Summary

Like thermopower, Nernst coefficient in HFs is largely enhanced over a wide T range.

New insight concerning Kondo scattering can be obtained by Nernst measurement.

For CeCu2Si2, Kondo scattering seems able to fully account for its thermopower. While for its dilute systems, skew scattering contribution develops to Nernst signal, which can even mask the Kondo scattering contribution.

Systematic study on different Kondo systems desired.