Ferromagnetic Phase Transition of Gadolinium

Purpose:

to measure the temperature dependence of heat capacity for Gd near the Curie point

Apparatus:

- Gd sample and Al sample each glued to C heater resistor
- Pt resistance thermometer
- Lock-In Amplifier
- Digital Voltmeter
Introduction:
- Heat capacity $C = \frac{Q}{\Delta T}$
- Specific heat $c = \frac{C}{m}$
- Curie point is where object loses its ferromagnetism
- Thermal agitations increase internal energy and $C$ below Curie point

Methods:
- AC current through resistor (behaves like heater)
- DC current through Pt thermometer
- Measure $V_{li}$ and $V_{dc}$ which are proportional to $T_{ac}$ and $T_{dc}$ respectively
- $C_{tot} = 0.136 \ g(w) \ f(w) \ Po \ I_{pt} \ 1 / V_{li}$, where
- $f(w)$ accounts for heat capacity of heater and thermometer, and
- $g(w)$ accounts for capacitor used to eliminate large DC signal
- $f(w)$ depends on $t_b$ (for sample to reach equilibrium with bath) and $t_{int}$ (for sample, heater, and thermometer to reach equilibrium with each other).

- Measure $t_b$ by letting sample cool with no AC current. (Cooling curve follows exponential decay with slope equal to $-1/t_b$.)

- Measure $t_{int}$ by recording $V_{li}$ as a function of frequency and comparing to product $f(w)g(w)$.

- Fit $C_{al}+pt+h_{tr}$ to linear function $A + BT$.

- $C_{gd} = C_{gd}+pt+h_{tr} - (A + BT) + C_{al}$, where $C_{al}$ is taken to be $0.0718$ J.
V\_li v. V\_dc for Gd (left) and Al (right)
ln(V_{dc}) vs. t for Gd (left) and Al (right)

Slope = -1.33286 ± .04847 1/s, so 
t_b = 3.75 s

Slope = -1.02466 ± .05121 1/s, so 
t_b = 4.88 s
Comparison of $V_{li}$ v. $w$ and $fg$ v. $w$ for Gd

By comparison we determined that $t_{int}$ was about .5 s.
V_li v. w and fg v. w for Al

By comparison, we see that \( t_b \) is 0.5 s.
C\_al+pt+htr \ v. \ T

Fit given by \( y = 0.09066 + 2.7362 \times 10^{-4} T \)
Using relationship \( c_{gd} m = C_{gd} = C_{gd}^{\text{pt+htr}} - (A + BT) + C_{al} \), and the fit from previous slide,

\[ c_{gd} \text{ v. } T \]
Comparison of $\ln(V_{dc})$ v. $t$ at 300 K (left) and 275 K (right)

Slope = $-1.33286 \pm .04847$ 1/s

Slope = $-1.24800 \pm .09261$ 1/s
Conclusions:

- Theoretically, there should have been sharp drop off at Curie temperature (~ 291 K)
- However, we found a smooth decline centered at ~ 285 K
- Also, the curve should show the specific heat increasing as temperature increases up to the Curie point
- But we were limited in our temperature range and did not observe this trend
- Could be due to poor responsiveness of the lock-in amplifier or poor thermal conductivity
- Theoretically, peak should be sharper from lower temperatures than experimentally observed (according to Jeong, etc. in Nov. 1991 Journal of Applied Physics)