Department of Physics
Summer 2024
Nonequilibrium Thermodynamics
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https://www2.physik.uni-muenchen.de/lehre/vorlesungen/sose_24/thermodynamik/index.html

Sheet 07

Discussion: Thursday 27.06.2024

Exercise 1 Onsager relations and thermoelectric phenomena

In this exercise, we consider the Seebeck and Peltier effect to verify the Onsager relation.

- Seebeck effect:
  1. Describe the Seebeck effect and the experimental setup to measure it.
  2. Start from the (one-dimensional) expression for the density current j_n in terms of the Onsager coefficients as derived in the lecture,
  $$j_n = -\frac{1}{T^2} L_{nq} \frac{\partial}{\partial x} T + \frac{1}{T} L_{nn} E \tag{1}$$
  with the electric field E and the temperature T. For an ideal voltmeter, $\mathbf{j}_{el} = -e\mathbf{j}_n = 0$. Using the approximation $\int TE\mathrm{d}x \approx T \int E\mathrm{d}x = -T\Delta\phi$, derive
  $$\Delta\phi = -\frac{L_{nq}}{TL_{nn}} \Delta T \tag{2}$$
  Use this to derive an expression for L_{nq} in terms of the thermoelectric power $\epsilon = -(\Delta\phi/\Delta T)$.
  3. Using the values from Tab. 1, calculate $L_{nq}(L_{nn})$.
- Peltier effect:
  1. Describe the Peltier effect and the experimental setup to measure it.
  2. Again, start from the expressions for the density current $\mathbf{j}_n$ and the heat current $\mathbf{j}'_q$ in terms of the Onsager coefficients derived in the lecture, Eq. (1) and
  $$\mathbf{j}'_q = -\frac{1}{T^2} L_{qq} \frac{\partial}{\partial x} T + \frac{1}{T} L_{qn} E, \tag{3}$$

Thermocouple	Temperature T in Celsius	Π/T in $\mu\mathrm{VK}^{-1}$	ϵ in $\mu\mathrm{VK}^{-1}$	L_{qn}/L_{nq}
Cu-Al	15.8	2.4	3.1	
Cu-Fe	0	-10.16	-10.15	
Fe-Hg	18.4	16.72	16.66	

Tabelle 1: Experimental data from Miller et al., Chem. Rev. 60 (1960)

with the electric field E and the temperature T. For the Peltier effect, we consider $\frac{\partial}{\partial x}T = 0$. Derive

$$L_{qn} = L_{nn}\frac{j'_q}{j_n} \tag{4}$$

with the Peltier heat $\Pi = \frac{j'_q}{j_n}$. Use this to derive an expression for L_{qn} in terms of the Peltier heat.

3. Using the values from Tab. 1, calculate $L_{qn}(L_{nn})$.

- Check the Onsager relation L_{qn}/L_{nq}.
- Assuming $L_{qn}/L_{nq} = 1$, derive the relation between the thermoelectric power and the Peltier heat.