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Molar heat capacity

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Contents

1. Motivation

The aim of this experiment is to determine the specififc heat capacity C of copper and its temperature dependency at low temperatures and room temperature. Therefore the specififc heat capacity at consant pressure C_p is measured and translated to the specififc heat capacity at constant volume C_V. Different models to describe the temperature dependency are compared and experimentally tested. These are the classical model, the Einstein-Model and the Debye-Model. Furthermore the *Debye Temperature* Θ_D is derived from the experiment's results and compared with the model's theoretical expectations.

2. Theory

The heat capacity of a material describes the amount of heat that is needed to increase the temperature of a certain amount of the material for 1 K. In general it can be calculated as

$$C = \frac{\delta Q}{\delta T}$$

where δQ is the input heat and δT the change in temperature. Most often the molar heat capacity c^{m} is used, but also the heat capacity per mass c^{mass} or the heat capacity per volume c^{vol} can be applied. As mentioned before, it is differentiated between heat capacity at constant Volume C_V and constant pressure C_p. For C_V the equation

$$C_V = \left.\frac{\delta U}{\delta T}\right|_{\mathbf{V}} \tag{1}$$

can be used to calculate the heat capacity, where U is the internal energy of the system. Experimentally, it is often easier to measure the heat capacity

$$C_p = \left.\frac{\delta Q}{\delta T}\right|_{\mathbf{p}}$$

at constant pressure because most materials expand when being heated. The deviation of C_p and C_V can be corrected using

$$C_p - C_V = TV\alpha_V^2 B \tag{2}$$

where α_V is the volumetric expansion coefficient and B the so called bulk module.

2.1. Classical Theory of heat capacity

In classical thermodynamics the Equipartition theorem states that the thermal energy of a solid is evenly distributed on its degrees of freedom and every degree of freedom corresponds to $\frac{1}{2}k_B T$ of kinetic and potential energy respectively. k_B is the Boltzmann constant. Assuming a crystal of N unit cells (1 atom per cell) this results in a total internal energy of

$$U = U^{\mathrm{eq}} + 3N \cdot 2\frac{1}{2}k_B T = U^{\mathrm{eq}} + 3Nk_B T.$$

Using Equation 1 the heat capacity at constant volume reads

$$C_V = 3Nk_B.$$

For the molar heat capacity the *Dulong-Petit* law

$$c_V^m = 3R \tag{3}$$

can be derived. Here $R = N_A k_B$ is the gas constant and N_A the Avogadro constant (number of atoms in 1 mol). The classical approach leads to a heat capacity that is material- and temperature independent. Experimental results however show that at low temperatures the heat capacity is proportional to T^3 and only approaches the classical value for C_V at higher temperatures. Also a dependance on the material can be noticed in experiments. Quantum mechanical effects have to be taken into account to explain this behaviour.

2.2. The Einstein-Model

3. Durchführung

4. Auswertung

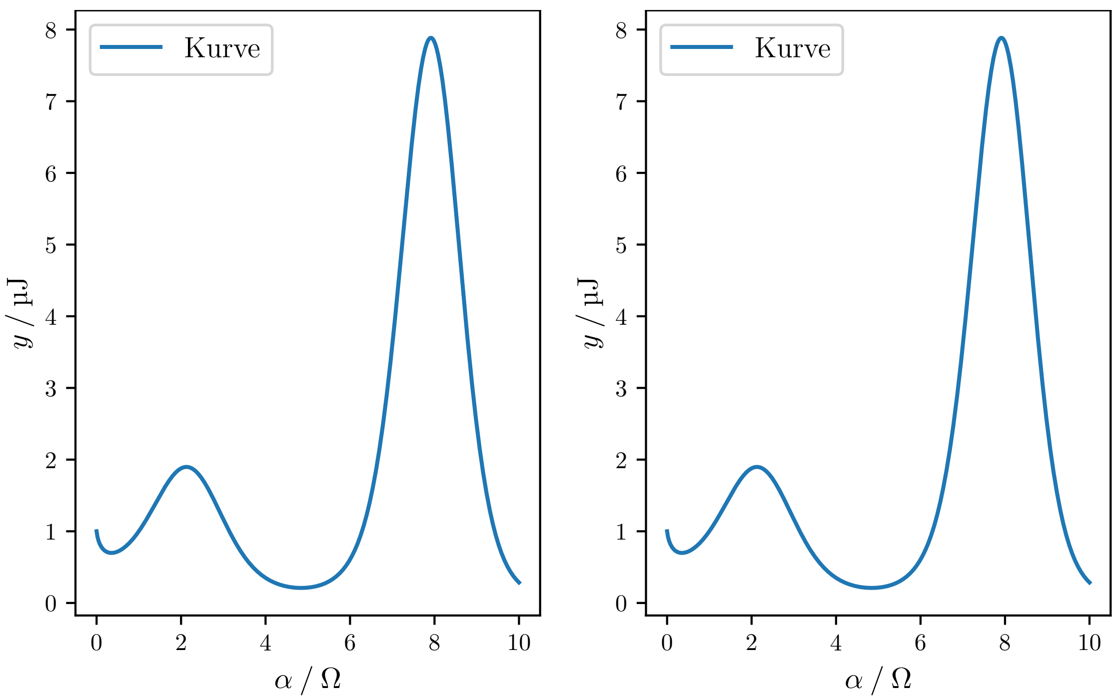

Figure 1: Plot.

Siehe Figure 1!

5. Diskussion

A. Anhang

A.1. Originaldaten