W 9e Specific Heat Capacity of Solids and Liquids

Tasks

1 Determine the heat capacity of a calorimeter involving an electrical heater filled with water!

2 Determine the specific heat capacity of two different metal objects!

3 Determine the molar heat capacity of the solid objects, and check the *Dulong-Petit* law!

Additional task: Determine the specific heat capacity of a liquid!

Literature

Physics, P. A. Tipler, 3rd Edition, Vol. 1, 16-1, 16-4, 16-7
University Physics, H. Benson, Chapt. 19
Physikalisches Praktikum, Hrsg. D. Geschke, B. G. Teubner Verlag Stuttgart-Leipzig, 12. Auflage, S. 132 - 136, S. 151
http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/spht.html

Accessories

calorimeter with electrical heating and magnetic stirring device, laboratory power supply, two digital multimeters, digital thermometer, test objects, balance

Keywords for preparation

- calorimeter, construction, heat capacity, heat losses, temperature-time-diagram
- experimental determination of heat capacities using the exchange of heat
- specific and molar heat capacity, 1st law of thermodynamics,
- *Dulong-Petit* law, equipartition theorem
- temperature dependence of the specific heat capacity

Remarks

The temperature measurement is carried using a digital thermometer. The determination of the heat capacity of the calorimeter filled with liquid is realized by electrical heating (electric power $P_{el} = UI$ = const, voltage U and current I are measured by digital multimeters) in *task 1*. The measurements shall be performed with water as calorimeter liquid.
The energy balance can be written by

$$\Delta Q = C_{ges}\,\Delta T = P_{el}\,\Delta t = U\,I\,\Delta t \quad . \tag{1}$$

The total heat capacity C_{ges} is the sum of the heat capacity of calorimeter C_K and the heat capacity of water $C_w = m_w\, c_w$ filled into the calorimeter vessel. From equ.(1) follows

$C_{ges} = \dfrac{U\,I}{b}$, where $b = \Delta T/\Delta t$ is the averaged slope in the linear range of the temperature-time diagram.

The analysis in *task 1* is done by graphical determination of the slope $b = \mathrm{d}T/\mathrm{d}t$. From the value b and the values of voltage and current you can calculate C_{ges} and the value for $C_K = C_{ges} - C_w$.
It is also possible to calculate approximately the heat capacity of calorimeter C_K using the mass and the

specific heat capacity of the calorimeter (steel) vessel: $C_K = m_K\, c_K$; $c_K = 450\,\mathrm{J\,K^{-1}kg^{-1}}$.
In *task 2* the test object is suspended into boiling water. Afterwards you have to transfer the heated test object into the calorimeter filled with water as fast as possible. Avoid the transport of hot water.

The heat energy balance $Q_{out} = Q_{in}$ with

$Q_{out} = c_f\, m_f\, (\vartheta_f - \vartheta_m)$ (c_f, m_f and ϑ_f are specific heat capacity, mass and temperature of the solid test object, respectively; ϑ_m is the mixture or final temperature)

$Q_{in} = (c_w\, m_w + C_K)\,(\vartheta_m - \vartheta_w)$ (c_w, m_w and ϑ_w are specific heat capacity, mass and temperature of the liquid (water), respectively; C_K heat capacity of calorimeter)

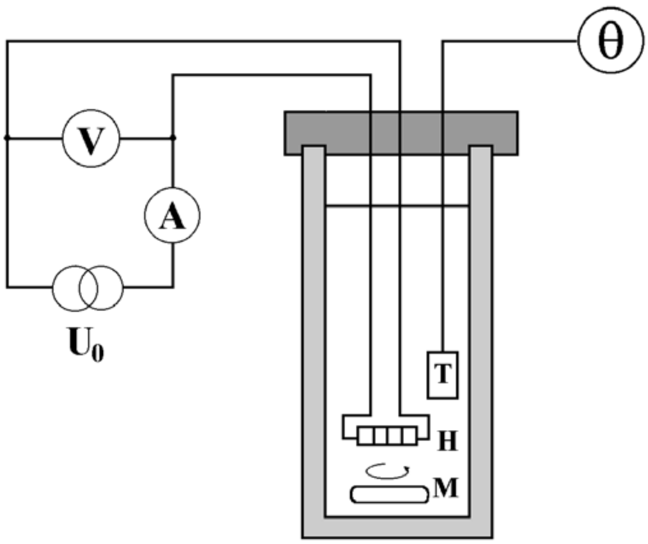
gives

$$c_f = \frac{(c_w\, m_w + C_K)\,(\vartheta_m - \vartheta_w)}{m_f\,(\vartheta_f - \vartheta_m)} \quad .$$

Evaluate the equation to estimate the propagation of errors!

For the measurements in *tasks 1* and *2* you have to note the temperature-time digram (preperiod about 3 minutes to check the initial temperature, main or mixture period and the period after the mixture process, to control the equilibrium state, compare Fig. 2 ...4). Whilst the experiment is in progress the magnetic stirring device must work. The mass of the test solids have to be measured using a balance.

Experimental setup of experiment W 9 (Fig. 1)



V voltmeter
A amperemeter
U_0 laboratory power supply
θ digital thermometer
T thermosensor
H heater
M magnetic stirrer

In this experiment the heat capacity of water is assumed to be constant in the temperature range considered ($c_w = 4180\,\mathrm{J\,K^{-1}}kg^{-1}$). In the case of the specific heat of the test objects you will determine an averaged value.

The mixture temperature ϑ_m in *task 2* is determined by extrapolation the curves plotted, as the sketch in Fig.2 shows. The temperatures before and after heat exchange are not constant in the rule because of the exchange of heat with the surroundings.
For the evaluation you draw a straight line parallel to the temperature axis in the graph of temperature rise, so that the shaded parts in Fig.2 are equal in area. The temperatures ϑ_m and ϑ_w are read off at the points where the straight line intersects the extended approximated linearized curves I and II.

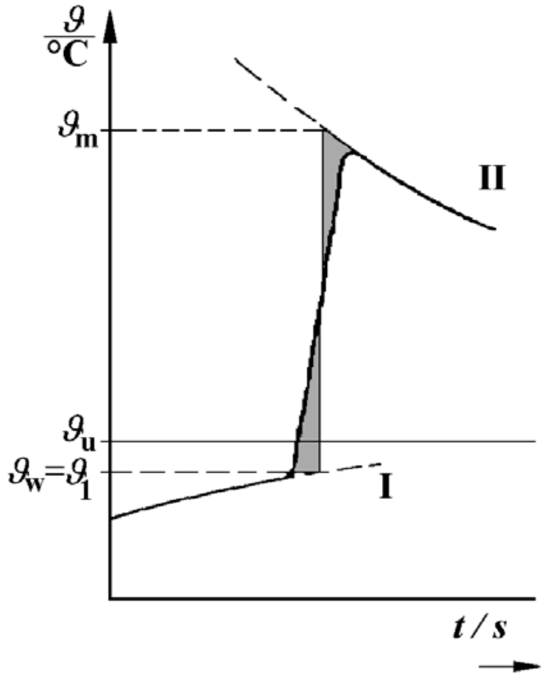


Fig. 2
Determination of the initial ϑ_1 temperature and the mixture temperature ϑ_m in the method of mixture experiment *task 2* when heat loss takes place. ϑ_u is the temperature of the surrounding atmosphere (ambient temperature).

Experimental examples [Digital temperature measurings]

Fig. 3

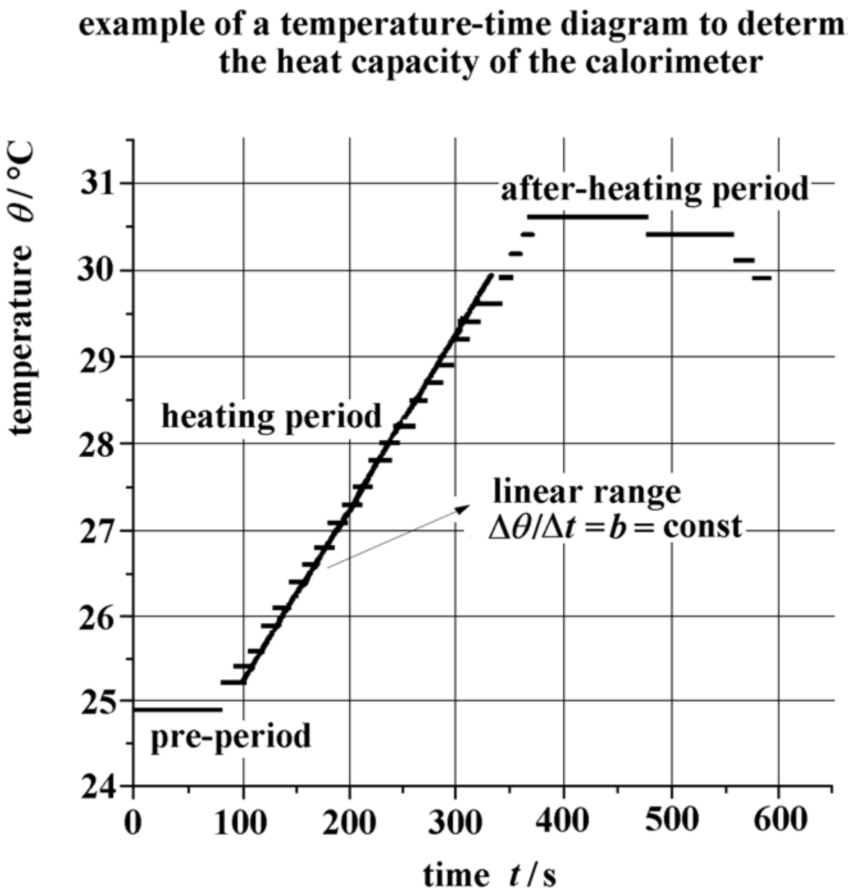
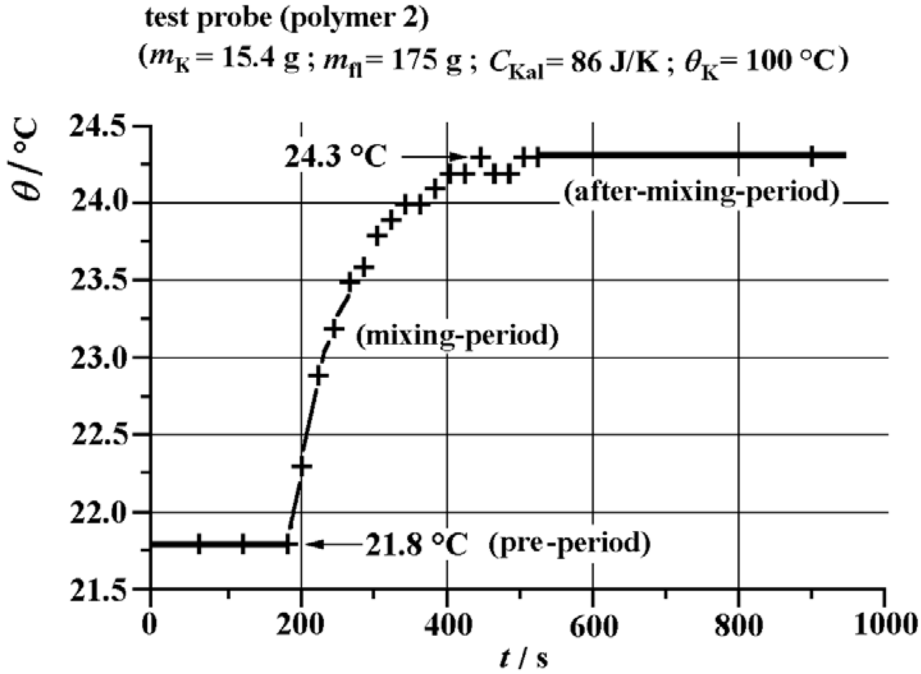


Fig. 4


test probe (polymer 2)
(m_K = 15.4 g ; m_{fl} = 175 g ; C_{Kal} = 86 J/K ; θ_K = 100 °C)
θ / °C
24.5
24.0
23.5
23.0
22.5
22.0
21.5
24.3 °C
(after-mixing-period)
(mixing-period)
21.8 °C
(pre-period)
0
200
400
600
800
1000
t / s