Heat

Heat quantity
Heat capacities

LD Physics Leaflets

P2.3.2.1

Determining the specific heat of solids

Objects of the experiments

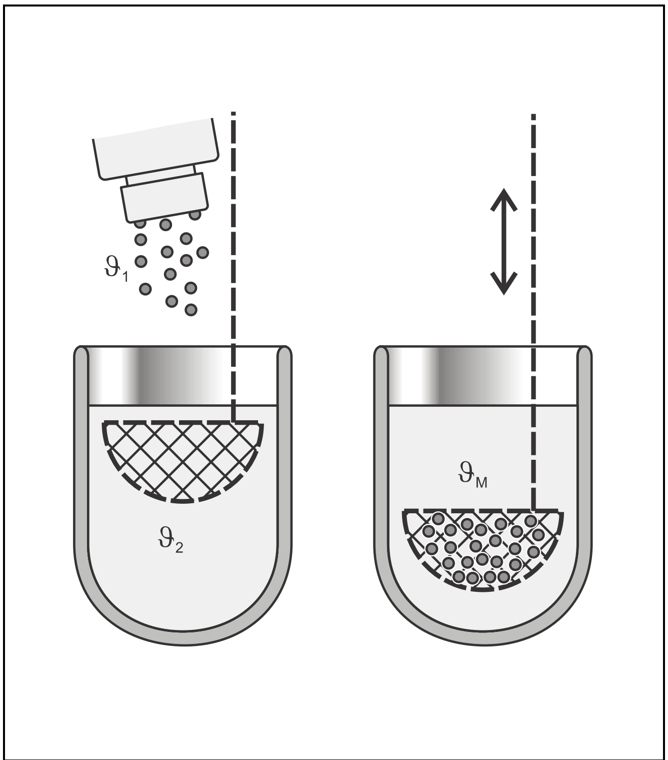
- Mixing cold water with heated copper, lead or glass shot and measuring the mixture temperature.
- Determining the specific heat of copper, lead and glass.

Principles

The heat quantity ΔQ that is absorbed or evolved when a body is heated or cooled is proportional to the change of temperature $\Delta\vartheta$ and to the mass m:

$$\Delta Q = c \cdot m \cdot \Delta\vartheta \qquad \text{(I).}$$

The factor of proportionality c, the specific heat capacity of the body, is a quantity that depends on the material.



In this experiment, the specific heat capacities of different substances, which are available as shot, are determined. In each case the shot is weighed, heated with steam to the temperature ϑ_1 and then poured into a quantity of water that has been weighed out and that has the temperature ϑ_2. After the mixture has been carefully stirred, the pellets and the water reach the common temperature ϑ_M through heat exchange. The heat quantity evolved by the shot

$$\Delta Q_1 = c_1 \cdot m_1 \cdot (\vartheta_1 - \vartheta_M) \qquad \text{(II)}$$

m_1: mass of the shot
c_1: specific heat capacity of the shot

is equal to the heat quantity absorbed by the water

$$\Delta Q_2 = c_2 \cdot m_2 \cdot (\vartheta_M - \vartheta_2) \qquad \text{(III)}$$

m_2: mass of the water

The specific heat capacity of water c_2 is assumed to be known. The temperature ϑ_1 is equal to the temperature of steam. The unknown quantity c_1 can therefore be calculated from the measured quantities ϑ_2, ϑ_M, m_1 and m_2:

$$c_1 = c_2 \cdot \frac{m_2 \cdot (\vartheta_M - \vartheta_2)}{m_1 \cdot (\vartheta_1 - \vartheta_M)} \qquad \text{(IV).}$$

The calorimeter vessel too absorbs part of the heat evolved by the shot. Therefore, the heat capacity

$$C_K = c_2 \cdot m_K \qquad \text{(V)}$$

or the water equivalent m_K of the calorimeter vessel has to be taken into account. The absorbed heat quantity calculated in Eq. (III) is thus more precisely

$$\Delta Q_2 = c_2 \cdot (m_2 + m_K) \cdot (\vartheta_M - \vartheta_2) \qquad \text{(VI),}$$

and Eq. (IV) is extended to

$$c_1 = c_2 \cdot \frac{(m_2 + m_K) \cdot (\vartheta_M - \vartheta_2)}{m_1 \cdot (\vartheta_1 - \vartheta_M)} \qquad \text{(VII).}$$

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Apparatus

1 Dewar vessel	386 48
1 cover for Dewar vessel	384 161
1 copper shot, 200 g	384 35
1 glass shot, 100 g	348 36
1 lead shot, 200 g	315 76
1 school and lab. balance 610 Tare, 610 g	315 23
1 thermometer –10 °C to +110 °C	382 34
or	
1 temperature sensor NiCr-Ni	666 193
1 digital thermometer	666 190
1 steam generator, 550 W / 220 V	303 281
1 heating apparatus	384 34
1 beaker, 400 ml	664 104
1 stand base, V-shape, 20 cm	300 02
1 stand rod, 47 cm	300 42
1 Leybold multiclamp	301 01
1 universal clamp, 0 … 80 mm dia.	666 555
1 silicone tubing int. dia. 7 × 1.5 mm, 1 m	667 194
1 pair of heat protective gloves	667 614

Setup and carrying out the experiment

The experimental setup is illustrated in Fig. 1.

– Mount the heating apparatus in the stand material.
– Fill water into the steam generator, close the device cautiously, and connect it to the top hose connection of the heating apparatus (steam inlet) with silicone tubing.
– Attach silicone tubing to the bottom hose connection of the heating apparatus (steam outlet), and hang the other end in the beaker. See to it that the silicone tubings are securely seated at all connections.
– Fill the sample chamber of the heating apparatus as completely as possible with lead shot, and seal it with the stopper.
– Connect the steam generator to the mains, and heat the shot for about 20–25 minutes in the heating apparatus flowed through by steam.

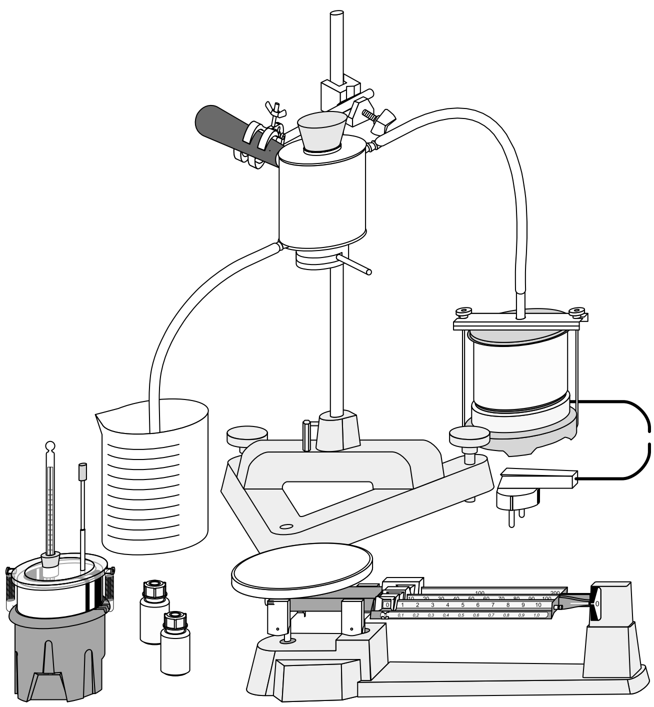
In the meantime:

– Determine the mass of the empty Dewar vessel, and fill in about 180 g of water.
– Mount the cover for the Dewar vessel and insert the thermometer or the temperature sensor respectively.
– Measure the temperature ϑ_2 of the water.
– Open the cover of the Dewar vessel and shift it aside; leave the mesh for samples of the cover in the Dewar vessel.

– Drop the shot with the temperature of 100 °C into the mesh for samples, close the cover, and thoroughly mix the water with the shot.
– Read the mixture temperature when the temperature of the water stops rising.
– Determine the additional mass m of the shot.

– Repeat the experiment with copper and glass shot.

Fig. 1 Experimental setup for determining the specific heat of solids.



Measuring example

Mass of the water: m_1 = 180 g

Temperature of the shot: ϑ_2 = 100 °C

Table 1: Measured values for determining the specific heat capacities

substance	$\frac{m_2}{\mathrm{kg}}$	ϑ_1	ϑ_M
lead	77	24.5 °C	25.4 °C
copper	69	24.0 °C	26.2 °C
glass	19	23.8 °C	24.9 °C

Evaluation

Water equivalent of the calorimeter: m_K = 23 g

specific heat capacity of water: $c_2 = 4.19 \frac{\mathrm{kJ}}{\mathrm{K \cdot kg}}$:

Table 2: Specific heat capacities determined experimentally and the corresponding values quoted in the literature

substance	$\frac{c}{\frac{\mathrm{kJ}}{\mathrm{K \cdot kg}}}$	$\frac{c}{\frac{\mathrm{kJ}}{\mathrm{K \cdot kg}}}$
	experiment	literature
lead	0.133	0.1295
copper	0.367	0.385
glass	0.656	0.746

In Table 2, the specific heat capacities calculated according to Eq. (VII) are given. The agreement with the values quoted in the literature is satisfactory.

Results

The specific heat capacities of the solids studied depend on the material and are considerably smaller than the specific heat capacity of water.

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