Specific heat capacity of solids (Item No.: P1428901)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 14-16	Thermal physics	States of matter: Melting, boiling, evaporation	Specific heat capacity of solids

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	50 Minutes	2 Students

Additional Requirements:

- scale
- calorimeter 500 ml (04401-00) or self made with 400 ml beaker with styrofoam shell
- matches or lighter
- oven cloth f.e.

Experiment Variations:

Keywords:

heat capacity, thermal energy, heat storage, material constant, calorimeter

Overview

Introduction

Thermal energy can be stored in different bodies. The amount of energy thereby depends on the material defined by its specific heat capacity. Water, for example, can take a lot more energy than the same mass of a solid. Within this experiment, the specific heat capacity of different metals is determined.

Educational goal

This experiment shows that different materials can store thermal energy to a different extent depending on a material-specific constant called the specific heat capacity. The capacity can be determinded via the absorbed energy Q, the mass of the body m_k and the temperature difference $\Delta\vartheta$ before and after the energy absorption:

$$c_k = \frac{Q}{m_k \cdot \Delta\vartheta}\,.$$

Equipment

Position No.	Material	Order No.	Quantity
1	Demo Physics board with stand	02150-00	1
2	Holder for Cobra4, magn.	02161-10	1
3	Holder for burner on fixing magnet	02161-00	1
4	Holder for wire gauze on fix. magnet	02163-00	1
5	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
6	Glass beaker BORO 3.3, 400 ml, short form	46055-00	1
7	Glass beaker BORO 3.3, 600 ml, short form	46056-00	1
8	Graduated cylinder 100 ml	36629-01	1
9	Pipette with rubber bulb	64701-00	1
10	Metal bodies, set of 3	04406-00	2
11	Fishing line, l. 20m	02089-00	1
12	Clamping holder, d = 28..36 mm, fixing magnet	02151-06	1
13	Clamping holder, d = 0..13 mm, fixing magnet	02151-07	1
14	Support plate on fixing magnet	02155-00	1
15	Butan burner with cartridge, 220 g	32180-00	1
16	Boiling beads, 200 g	36937-20	1
17	Cobra4 Mobile-Link 2	12620-10	1
18	Cobra4 Display-Connect TX, transmitter for using the Cobra4 Mobile-Link with large-scale displays	12623-00	1
19	Cobra4 Display-Connect RX, receiver for using the Cobra4 Mobile-Link with large-scale displays	12623-01	1
20	Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
21	Immersion probe, NiCr-Ni, steal, -50...400°C	13615-03	1
22	Large-scale display	07157-93	1


Fig. 1a: Equipment of the measuring part


Fig. 1b: Equipment for the experiment

Set-up & Implementation

Set-up

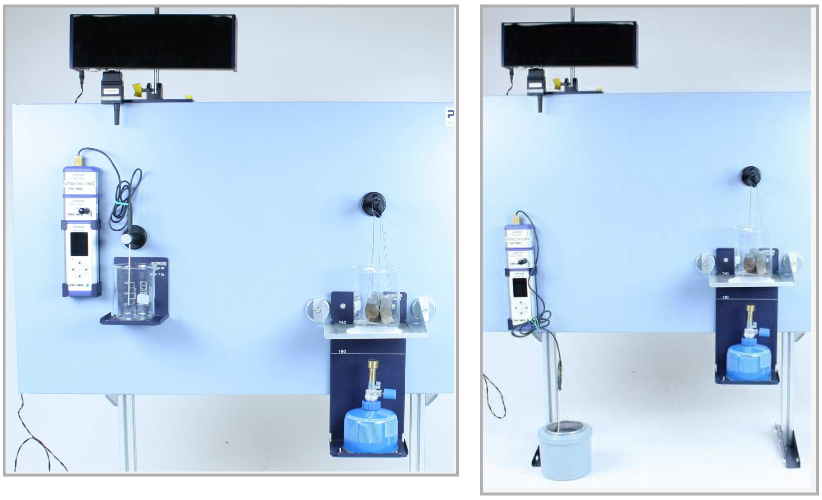
Set-Up of the measurment instruments:

1. Stick the Cobra4 Display connect for large-scale display showings and the Cobra4 Sensor-Unit 2x Temperature to the Cobra4 Mobile-Link 2. Connect an immersion probe (NiCr-Ni) to the temperature sensor-unit.
2. Place the Cobra4 Mobile-Link to the board using the magnetic holder and turn it on by pressing the green On-button.
3. Link the receiver of the Display-Connect unit to the large-scale display.
4. Insert the power plug in the fitting port of the display and plug in for power.
5. Attach the large-scale display to a rod with a clamp and afterwards attach it to the top of the magnetic board with a clamp on holder.

Set-up of the experiment according to fig. 2:

1. Place the holder for the burner at the bottom of the board, possibly far away from the temperature sensor.
2. Set the holder for the wire gauze at the hight marked 240 if using the butan burner. In case of using a bunsen burner use mark 180. Place the wire gauze on the holder.
3. Then place the 600 ml beaker on the wire gauze.
4. Position the wide clamping holder above the beaker. Within the implementation this is the place to hang the metal pieces.
5. Set the supporting plate directly next to the Cobra4 Mobile-Link on the board. This is, where the calorimeter is placed. In case it is to big it can also be placed underneath the board.
6. Place the small clamping holder above the calorimeter and insert the immersion probe (temperature sensor).

Fig. 2: Set-up with beaker (left) or calorimeter (right)



Anmerkung
Das Kalorimeter ist zusätzlich. Alternativ zu einem gekauften Kalorimeter kann es selber gebaut werden, in dem für das 400-ml-Becherglas aus Styropor eine Ummantelung gebaut wird (sowohl von den Seiten als auch von unten). Tatsächlich kann der Versuch auch einfach nur mit Becherglas durchgeführt werden. In diesem Fall sind allerdings größere Wärmeverluste vorhanden. Die Ergebnisse weisen also einen größeren Fehler auf.

Implementation

1. Get the weight of the metal bodies (round decimal place). Weigh always both similar pieces together.

2. Cut off three about 40 cm piece of fishing line and through two similar metal pieces respectively, tying them together.

3. Hang the metal bodies to a clamp holder as shown in fig.3 . They should be hung in such a way that they can be taken off individually.
Lower the metal into the beaker so that the bodies dangle about 1 cm above the bottom.

4. Fill about 350 ml of water into the beaker. Make sure the metal bodies are completely covered. Add a couple of boiling beads.

5. Turn on the burner, place it in the holder and heat up the water until boiling.

6. Fill exactly 150 g of cold water in the calorimeter/400 ml beaker. Measure it out on a scale using the pipette. 150 g waters equal 150 ml (can be measured with the graduated cylinder). Because the mass of the water is important, it is proposed to use the scale.

7. Position the immersion probe in clamping holder in such a way that the sensor extents approx. 1 cm into the water in the calorimeter/beaker.
8. Measure the inital temperature T_W of the water in the calorimeter and take it down.
9. As soon as the water is boiling, turn off the burner and/or take it away.

10. Take out the aluminum, let them drain shortly and yield it quickly into the water in the calorimeter. Again they have to be fully covered and may not touch the immersion probe.

11. Stir the water thoroughly and measure the mixing temperature T_m when the temperature is constant.

12. Remove metal and water from the calorimeter, rinse it out with cold water and dry it up. Then repeat the experiment with steal and brass.

Fig. 3: Attaching the metal to the clamp.

Note:

- For all three experiments the initial water temperature should have about the same temperature. Then, a simple comparison between the mixing temperatures shows which material can save the energy best. This is most easily accomplished by taking a second 600 ml beaker and fill it with a minimum of 500 ml of water and set it aside for as a storage vessel.

- The duration of the experiment can be reduced a lot, if the first three points are prepared before class. Furthermore, it is adviable to fill the metal inserted beaker with water which is already heated up, instead of fresh and cold tab water. In that way, the minutes until boiling can be reduced effectivly.

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Results & Evaluation

Results

For all metals, following results are equal:

Mass of the cold water	m_w =	150 g
Mass of two metal bodies	m_k =	120 g
Temperature of the hot bodies	T_k =	100°C

The measurement results for the metals are found in table 1.

Table 1: Temperature measurement for the different metals

	T_w [°C]	T_m [°C]
Aluminum	21.1	31.1
Steal	21.3	27.0
Brass	21.3	26.0

Evaluation

A simple comparison can show, which material could store more energy and therefore transfer more energy to the water. For that the difference between mixing temperature T_m and initial temperature T_W is calculated:

$$\Delta T = T_m - T_W.$$

The results can be found in table 2.

For a quantivativ evaluation Für die quantitative evaluation the energy Q absorbed from the mass of water m_W has to be calculated.

$$Q = c_W \cdot m_W \cdot \Delta T$$

c_W = 4,19 J/g°C is the specific heat capacity of water. The results are also displayed in table 2.

Within this simple evaluation, the heat capacity of the calorimeter is neglected. Therefore, the energy Q_k provided by the metal equals the energy absorbed from the water.

$$Q = Q_k = c_k \cdot m_k \cdot (T_k - T_m)$$

The specific heat capacity of solids is determined by

$$c_k = \frac{Q}{m_k \cdot (T_k - T_m)}.$$

Table 2: Results of the evaluation

				Literature value
	ΔT [°C]	Q [kJ]	c_k [J/g°C]	c_k [J/g°C]
Aluminum	10.2	6.4	0.78	0.896
Steal	5.7	3.6	0.41	0.45
Brass	4.7	3.0	0.34	0.385

It becomes obvious, that the calculated capacity gained from the measurements are all slightly smaller then the literature values.

Remark

1. The metal does not only provide energy for the water but also for the calorimeter. The heat capacity of the (half filled) calorimeter is about 40 J/°C, the one of water is 229 J/°C (for the calorimeter 04401-00, with styro foam the value is again slightly differnt). The error therefore is about 15%.
2. Further errors occure while bringing the hot metal pieces into the calorimeter. First of all water droplets are included and secondly the metal is already cooling off. The first error increases the mixing temperature, the second error decreases the temperature towards accurate procedure.
3. The energy Q in table 2 has a kJ unit because the measured temperatures, which apply to the evaluation f.e. ΔT = 5.7 °C for steal, only has two digits. Therefore, the result should only have to digits also meaning 3.6 kJ and not 3600 J. The difference gets clear if the students do the calculation for both cases with ΔT = 5.6°C and ΔT = 5.8°C also. Both results would easily be possible if the 1/10 degree thermometer fluctuates about 1 site in the last digit.

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