Calorimetric temperature measurement with measureAPP (Item No.: P1044368)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 16-19	Thermodynamics	Calorimetry	Calorimetric temperature measurement with measureAPP

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

Additional Requirements:

- Apple iPad

Experiment Variations:

Keywords:

Calorimetry, Mixture temperature

Task and equipment

Information for teachers

The temperature of a hot metal object is to be determined in a mixing experiment.

Notes on set-up and procedure

1. Because of the high temperature, the hanging loop must be made using wire instead of fishing line.
2. The wire should be at least 40 cm long.
3. There is a hissing sound when the hot body is immersed in the water because it is much hotter than 100 °C.
4. The aluminium body could be subject to damage in the burner flame - do not use it here.

Note
The temperatures of the two bodies should be about the same when they hang at the same position in the flame for the same length of time.
The temperatures of the metal bodies depends on how high above the flame and how long they hang. If they were hung, for example, for 5 minutes directly above the flame, then a temperature of 700 °C would be determined.
As this is a student experiment and the principle of temperature measurement is to be shown, it is sufficient to heat the bodies above the flame for 1 minute.
The measurement error is greater at higher temperatures.

Set-up

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Task and equipment

Task

Application

Calorimetry can also be used to determine the temperature of a hot object that is difficult to measured by any other method, e.g. because it is too hot for the thermometers available. The heat content of the object can be calculated from the mixture temperature that is reached in the calorimeter. The initial temperature of the object can be calculated from this when the capacity of the object is known. Another important application is the determination of the calorific value from different materials like wood, coal or gas.

With calormetry it is possible to determine the calorific value of coal for example.

Task

How can the temperature of a hot object be determined?

Heat the metal object over a flame, put it into cold water in the calorimeter and determine the mixture temperature that is reached. Use this temperature to calculate the initial temperature of the object.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	1
2	Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
3	Immersion probe NiCr-Ni, steel, -50...400 °C	13615-03	1
4	Support base, variable	02001-00	1
5	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
6	Universal clamp	37715-00	1
7	Boss head	02043-00	1
8	Metal bodies, set of 3	04406-00	1
9	Lid for student calorimeter	04404-01	1
10	Agitator rod	04404-10	1
11	Felt sheet, 100 x 100 mm	04404-20	2
12	Beaker, low, BORO 3.3, 250 ml	46054-00	1
13	Beaker, low, BORO 3.3, 400 ml	46055-00	1
14	Beaker, low form, plastic, 100 ml	36011-01	1
15	Pipette with rubber bulb	64701-00	1
16	Graduated cylinder 100 ml, PP transparent	36629-01	1
17	Iron wire, d = 0.5 mm, l = 50 m	06105-00	1
18	Butane burner, Labogaz 206 type	32178-00	1
19	Butane cartridge C206, without valve, 190 g	47535-01	1

Position No.	Material	Order No.	Quantity
20	Apple iPad		1
21	PHYWE measure App		1

Download on the App Store

Set-up and procedure

Set-up

Fig. 1: Set-up

Caution!

1. The wire used for hanging must be 40 cm long so that the upper end does not get too hot.
2. The metal objects get very hot! Take care not to drop them.

Set-up

- Set the stand up as shown in Fig. 1.
- Thread a 40 cm long piece of wire through the brass body, bend it to a loop and hang it on the universal clamp.
- Make up a thermally insulating vessel (calorimeter) using two beakers (250 ml and 400 ml) and two felt sheets.
- Fill 200 ml of water in the calorimeter. Measure it out accurately from the plastic beaker using the graduated cylinder and the pipette.
- Push the agitator rod up through the appropriate hole in the calorimeter lid from below.

Procedure

- Connect the Cobra4 Sensor-unit 2 x Temperatur with the Wireless/USB-link. Now plug the Immersion probe NiCr-Ni, steel, -50...400 °C into the T1 socket of the Sensor-unit. Switch the Wireless/USB-link on.
- Connect your iPad via Wi-Fi with the Wireless/USB-link.
- Open the PHYWE measure App and select the sensor "2x temperature". Please make sure only the T1 measurement channel is activ.
- The preset sampling rate of 1 Hz is suitable for this experiment.
- Insert the temperature sensor through a hole in the calorimeter lid so that it dips in the water but does not touch the bottom.
- Start measured value recording in measureApp, a measured temperature value will now be recorded every second.
- Hang the brass body about 5 cm above the flame of the burner and heat it for one minute.
- During this, stir in the calorimeter – the temperature display should become constant.
- Transfer the brass body into the calorimeter and immediately close it.
- Carefully stir the water in the calorimeter so that heat is evenly distributed.
- End measurement, when the temperature slowly decreases, or at the latest after 100 s. Save afterwards. For further analysis open the measurement under "my measurements".
- Repeat the experiment in the same way with the iron body.

Evaluation

The two metal bodies have the same mass m_{metal} = 60 g.
The mass of water in the calorimeter is m_{water} = 200 g.
The specific heat capacities are:
c_{water} = 4,2 J/(g· °C)
c_{brass} = 0,39 J/(g· °C)
c_{iron} = 0,45 J/(g· °C)

Assume that the calorimeter has a heat capacity corresponding to a water equivalent of 20 g or C = 84 J/°C.
When a metal body is transferred to the calorimeter, the temperature of the calorimeter, the water in the calorimeter and the metal body come to the common temperature $\vartheta_{\text{cal},2}$.

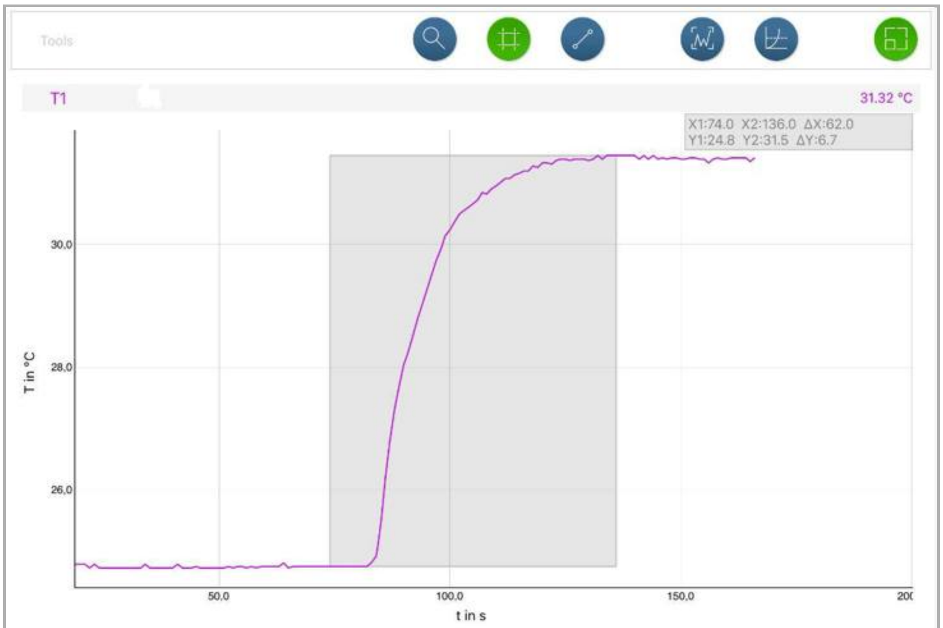

Fig. 2: Behaviour of the temperate display over time, with the measureApp "Survey" tool switched on. Example for brass

Protokoll: Kalorimetrische Temperaturmessung mit measureAPP

Auswertung - Frage 1

Wähle in der measureApp das „Vermessen"-Werkzeug, um die Anfangstemperatur im Kalorimeter $\vartheta_{\mathrm{Kal,1}}$ und die Mischungstemperatur im Kalorimeter $\vartheta_{\mathrm{Kal,2}}$ bei beiden Messkurven zu bestimmen; die Mischungstemperatur ist das Temperaturmaximum, das sich einstellt. Ergänze Tabelle 1.

Rechne die Temperaturdifferenz der Temperatur des Kalorimeters $\Delta\vartheta_{\mathrm{Kal}} = \vartheta_{\mathrm{Kal,2}} - \vartheta_{\mathrm{Kal,1}}$ vor und nach dem Überführen der Metallprobe ins Kalorimeter aus und ergänze Tabelle 1.

Messing	$\vartheta_{Kal,1}$ / °C	1 ±10	$\Delta\vartheta_{Kal}$ / °C	1 ±3
	$\vartheta_{Kal,2}$ / °C	1 ±10		
Eisen	$\vartheta_{Kal,1}$ / °C	1 ±10	$\Delta\vartheta_{Kal}$ / °C	1 ±5
	$\vartheta_{Kal,2}$ / °C	1 ±10		

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Auswertung - Frage 2

Wasser und Kalorimeter zusammen haben die Wärmekapazität

$$C_{\text{Kal}} = c_{\text{Wasser}} \cdot m_{\text{Wasser}} + C = 4,2 J/(g \cdot {}^{\circ}C) \cdot 200g + 84 J/{}^{\circ}C = 924 J/{}^{\circ}C$$

Die Wärmemenge, die das Metallstück abgibt, ist gleich der Wärmemenge, die das wassergefüllte Kalorimeter aufnimmt:

$\Delta Q = C_{\text{Kal}} \cdot \Delta\vartheta_{\text{Kal}} = 924 J/{}^{\circ}C \cdot \Delta\vartheta_{\text{Kal}}$ (1)

Berechne die Wärmemenge ΔQ nach (1), die das Kalorimeter aufnimmt und ergänze Tabelle 2.

Das Metallstück hat anfangs die unbekannte Temperatur $\vartheta_{\text{Metall,1}}$ und am Ende die Temperatur des Kalorimeters $\vartheta_{\text{Metall,2}} = \vartheta_{\text{Kal,2}}$ und für die Wärmemenge, die der Metallklotz abgibt, gilt:

$\Delta Q = c_{\text{Metall}} \cdot m_{\text{Metall}} \cdot \Delta\vartheta_{\text{Metall}} = c_{\text{Metall}} \cdot m_{\text{Metall}} \cdot (\vartheta_{\text{Metall,1}} - \vartheta_{\text{Kal,2}})$ (2)

so dass sich für die gesuchte Anfangstemperatur des Metallklotzes ergibt:

$\vartheta_{\text{Metall,1}} = \frac{\Delta Q}{c_{\text{Metall}} \cdot m_{\text{Metall}}} + \vartheta_{\text{Kal,2}} = \frac{C_{\text{Kal}} \cdot \Delta\vartheta_{\text{Kal}}}{c_{\text{Metall}} \cdot m_{\text{Metall}}} + \vartheta_{\text{Kal,2}}$ (3)

Rechne aus den Messwerten der Tabelle 1 mit Hilfe der Formel (3) die Anfangstemperaturen der Metallklötze aus und ergänze Tabelle 2:

	ΔQ / J	$\vartheta_{\text{Metall,1}}$
Messing	1 ±300	1 ±30
Eisen	1 ±300	1 ±30