Temperature of mixtures and the heat capacity of the calorimeter with measureAPP (Item No.: P1044168)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 16-19
Topic: Thermodynamics
Subtopic: Calorimetry
Experiment: Temperature of mixtures and the heat capacity of the calorimeter with measureAPP

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	10 Minutes	1 Student

Additional Requirements:

- Apple iPad

Experiment Variations:

Keywords:

Temperature equilibrium, Heat capacity, Mixture temperature

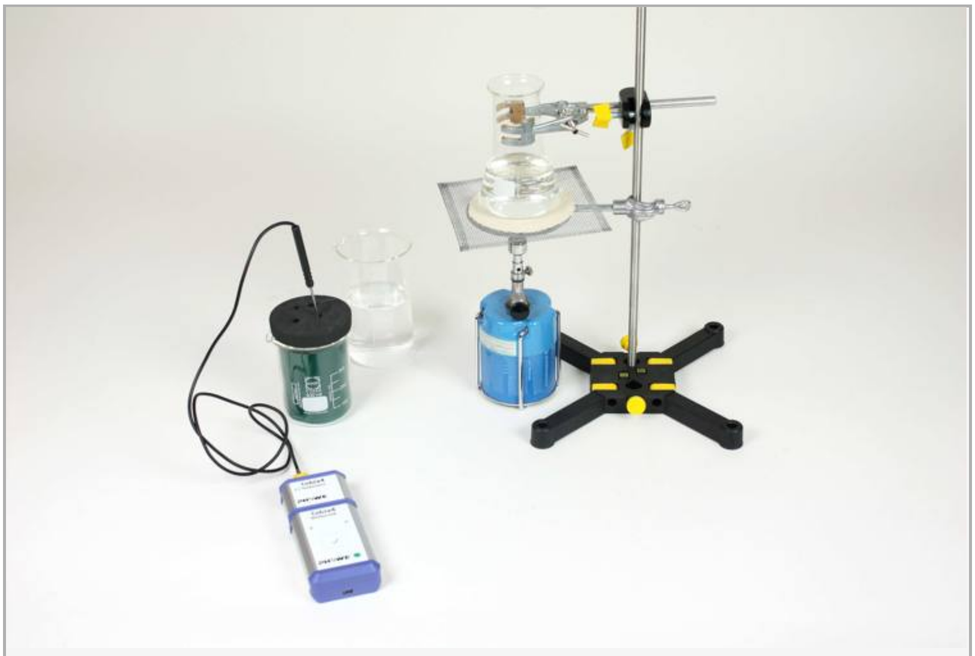
Task and equipment

Information for teachers

This experiment deals with the temperature of mixtures and the heat capacity of the calorimeter. Heated water is added to water at room temperature in the calorimeter. This is to ensure that the calorimeter contents are at as uniform a temperature as possible.
The temperature differences used can be kept small compared to experimental versions without Cobra4, as the electronic temperature sensor has a better resolution than a students thermometer with alcohol filling.
The water equivalents measured depend on how rapid the experiment is carried out and how much the “heated“ water is heated. Water equivalents around 20 g, corresponding to 84 J/°C, can be measured.

Notes on set-up and procedure

1. The temperature curve of the heating of the water need not be plotted as, without this, the relevant measured values do not get “hidden“ in a long measurement curve, but can be clearly seen.
2. Large temperature differences lead here to large measurement errors – we recommend that all parts and the stock water be at (uniform) room temperature. The water need not be too strongly heated.
3. The maximum values of the temperature curves are evaluated as relevant measured temperature values – the sensor is cooled in between so that they can be clearly seen.



Set-up

Temperature of mixtures and the heat capacity of the calorimeter with measureAPP (Item No.: P1044168)

Task and equipment

Task

Application

Quantities of heat distribute themselves so that finally all parts that are in contact with each other have the same temperature. If the heat capacities and the initial temperatures are known, then the final temperature can be predicted. Or, in reverse, the final temperature can be used to derive the heat capacity when the initial temperatures are known.
In our everyday life one mixture is well known: Milk and coffee. To get a feeling for the equilibrium temperature of two liquids we want to perform this experiment.

What is the equilibrium temperature of two liquids?

Another interesting point is the heat capacity of the calorimeter itself. This will also be figured out in this experiment.

Task

Which temperature results when amounts of water of different temperature are mixed in a calorimeter?

Heat different amounts of water with the butane burner and determine their temperatures. Mix them with a known amount of water in the calorimeter, the temperature of which you have previously measured. Measure the temperature of the mixture that results in the calorimeter.

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	Ring with boss head, i. d. = 10 cm	37701-01	1
9	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
10	Lid for student calorimeter	04404-01	1
11	Agitator rod	04404-10	1
12	Felt sheet, 100 x 100 mm	04404-20	2
13	Erlenmeyer wide neck,boro.,250ml	46152-00	1
14	Beaker, low, BORO 3.3, 250 ml	46054-00	1
15	Beaker, low, BORO 3.3, 400 ml	46055-00	1
16	Graduated cylinder 100 ml, PP transparent	36629-01	1
17	Pipette with rubber bulb	64701-00	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

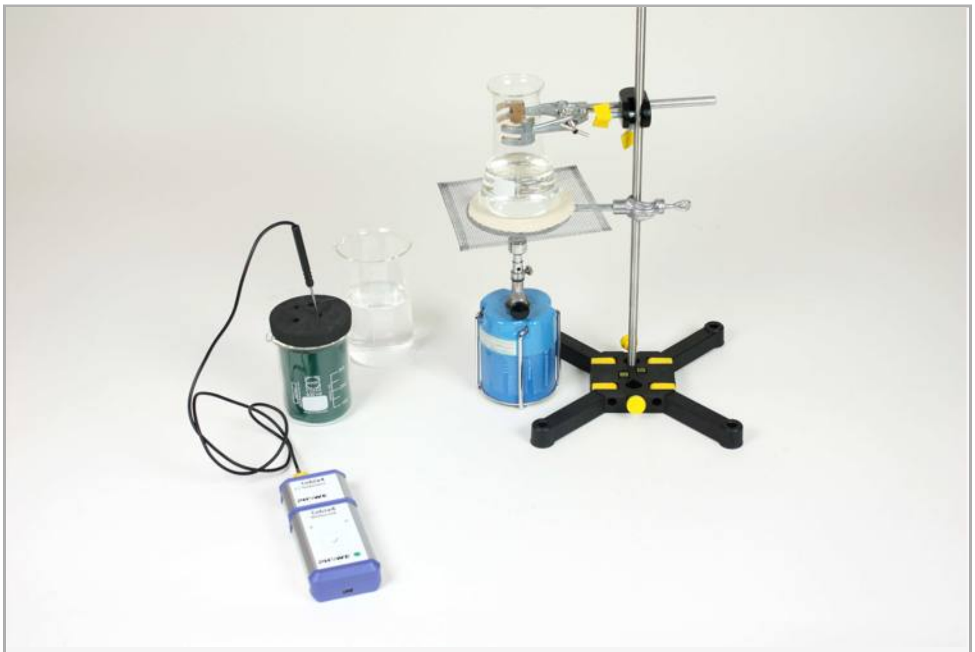


Fig. 1: Set-up

- Before starting the experiment, fill a beaker with water (0.5 to 1 litre, e.g. in a 1000 ml beaker, 36008-00) so that this comes to room temperature and so has the same temperature as the rest of the material for the experiment.
- Make up a thermally insulating vessel (calorimeter) using two beakers (250 ml and 400 ml) and two felt sheets.
- Push the agitator rod up through the appropriate hole in the lid from below.
- Set up the stand as shown in Fig. 1.

Procedure

Caution!
When the water is heated, the support ring and the wire gauze get very hot! When you are to transfer hot water, hold the Erlenmeyer flask at the upper rim only. Take care! Do not let the cable of the sensor touch the wire gauze!

- 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.
- Measure 50 ml of water from the stock vessel into the graduated cylinder (measure exactly using the pipette) and pour it into the calorimeter. Record the amount of water $m_{\mathrm{water,cal}}$.
- Put the lid with fitted agitator rod on the calorimeter and insert the temperature sensor so far through a suitable hole in the lid that it dips into the water but does not touch the bottom.
- Stir and wait until the temperature display remains constant. Record the initial temperature in the calorimeter $\vartheta_{\mathrm{cal,1}}$.
- Measure out 150 ml of water in the graduated cylinder and fill it into the Erlenmeyer flask. Record the amount of water $m_{\mathrm{water,Erl}}$
- Heat the water up by 15 to 25 °C with the burner.
- Stop heating. Cool the temperature sensor in the stock vessel.
- Start measured value recording in measureApp. A measured temperature value will now be recorded every second.
- Carry on measuring with the temperature sensor in the Erlenmeyer flask until the display remains constant.
- Remove the sensor from the heated water and put it briefly in the stock vessel so that it cools down.
- Fill the heated water into the calorimeter, fit the lid on and again insert the temperature sensor in the water through a hole in the lid.
- Stir the water in the calorimeter carefully throughout measurement, so that heat is evenly distributed.
- Stop measurement with when the temperature only slowly drops. Save afterwards. You can open the measurement at any time for further analysis under "my measurements".
- Pour the water out of the calorimeter and dry the calorimeter beaker.
- Proceed in the same way for Experiment 2, with 100 ml of water at ambient temperature in the calorimeter and 100 ml of heated water, as well as for Experiment 3, with 150 ml of water at ambient temperature in the calorimeter and 50 ml of heated water.

Evaluation

1. Use the "Survey"-tool in measureApp to evaluate the maximum values of the measurement curves. The first maximum value corresponds to the temperature of the heated water in the Erlenmeyer flask, $\vartheta_{\text{erl},1}$. The second maximum value corresponds to the mixed temperature in the calorimeter $\vartheta_{\text{cal},2}$.
2. The water from the Erlenmeyer flask cools by a temperature difference $\Delta\vartheta_{\text{erl}}$, whereas the water in the calorimeter heats up by a temperature difference $\Delta\vartheta_{\text{Kal}}$ The following is valid for the temperature differences:

$$\Delta\vartheta_{\text{erl}} = \vartheta_{\text{erl},1} - \vartheta_{\text{erl},2} = \vartheta_{\text{erl},1} - \vartheta_{\text{cal},2}$$

$$\Delta\vartheta_{\text{cal}} = \vartheta_{\text{cal},2} - \vartheta_{\text{cal},1}$$

3. Assuming that no heat is lost to the surroundings and also that no other sources of heat are active, then the total amount of heat is preserved: The heat quantity ΔQ_{erl},which the heated water releases is therefore the same as the heat quantity ΔQ_{\text{cal}}, that the cold water in the calorimeter takes up (assuming also that only the water plays a part here):

$$\Delta Q_{\text{erl}} = c_{\text{water}} \cdot m_{\text{water,erl}} \cdot \Delta\vartheta_{\text{erl}} \quad (1)$$

$$\Delta Q_{\text{cal}} = c_{\text{water}} \cdot m_{\text{water,cal}} \cdot \Delta\vartheta_{\text{cal}} \quad (2)$$

The mass of the water can be calculated from (1) and (2) using:

$$m_{\text{water,cal}} = m_{\text{water,erl}} \cdot \frac{\Delta\vartheta_{\text{erl}}}{\Delta\vartheta_{\text{cal}}} \quad (3)$$

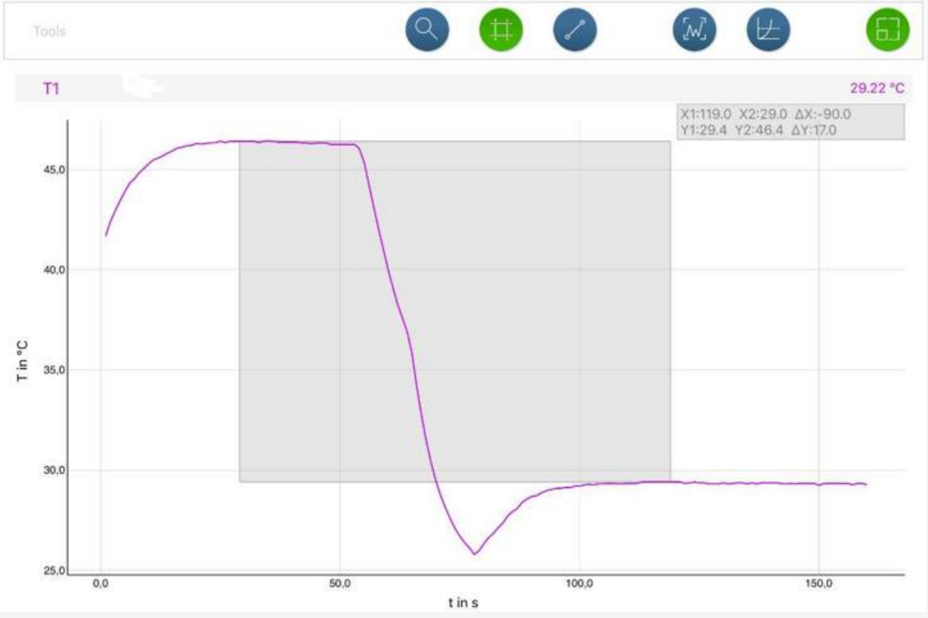


Fig. 2: Course of the temperature display of the temperature sensor against time, with the measureApp “Survey“ tool switched on.

Protokoll: Mischungstemperatur und Wärmekapazität des Kalorimeters mit measureAPP

Auswertung - Frage 1

Fülle das Messergebnisprotokoll (Tabelle 1) aus (Wasser hat die Dichte 1,00 g/ml). Das erste Maximum entspricht der Temperatur des erwärmten Wassers im Erlenmeyerkolben, $\vartheta_{\mathrm{Erl},1}$. Das zweite Maximum entspricht der Mischungstemperatur im Kalorimeter $\vartheta_{\mathrm{Kal},2}$.

Versuch 1	$m_{\mathrm{Wasser,Kal}}$ / g	50	$\vartheta_{\mathrm{Kal},1}$ / °C	1 ±2	$\vartheta_{\mathrm{Kal},2}$ / °C	1 ±2
	$m_{\mathrm{Wasser,Erl}}$ / g	150	$\vartheta_{\mathrm{Erl},1}$ / °C	1 ±2		
Versuch 2	$m_{\mathrm{Wasser,Kal}}$ / g	100	$\vartheta_{\mathrm{Kal},1}$ / °C	1 ±2	$\vartheta_{\mathrm{Kal},2}$ / °C	1 ±2
	$m_{\mathrm{Wasser,Erl}}$ / g	100	$\vartheta_{\mathrm{Erl},1}$ / °C	1 ±2		
Versuch 3	$m_{\mathrm{Wasser,Kal}}$ / g	150	$\vartheta_{\mathrm{Kal},1}$ / °C	1 ±2	$\vartheta_{\mathrm{Kal},2}$ / °C	1 ±2
	$m_{\mathrm{Wasser,Erl}}$ / g	50	$\vartheta_{\mathrm{Erl},1}$ / °C	1 ±2		

Auswertung - Frage 2

Trage die Temperaturdifferenzen $\Delta\vartheta_{\mathrm{Erl}}$ und $\Delta\vartheta_{\mathrm{Kal}}$ in Tabelle 2 ein. Berechne die Wassermenge im Kalorimeter $m_{\mathrm{Wasser,Kal}}$ gemäß (3) und trage sie ebenfalls in Tabelle 2 ein. Nähere Informationen dazu unter Auswertung in der Versuchsbeschreibung.

	$\Delta\vartheta_{\mathrm{Erl}}$ / °C	$\Delta\vartheta_{\mathrm{Kal}}$ / °C	$m_{\mathrm{Wasser,Kal}}$ / g
Versuch 1	1 ±2	1 ±2	1 ±5
Versuch 2	1 ±2	1 ±2	1 ±5
Versuch 3	1 ±2	1 ±2	1 ±5

Auswertung - Frage 3

Vergleiche die in der letzten Spalte von Tabelle 2 errechneten Werte mit den Wassermengen, die Du tatsächlich in das Kalorimeter gefüllt hast. Warum errechnet die Formel (3) höhere Werte? Welche Wärmekapazität wurde außer Acht gelassen?

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Auswertung - Frage 4

Die Differenz aus dem errechneten Wert für die Wassermenge und der tatsächlichen Wassermenge wird Wasserwert des Kalorimeters genannt. Gib den Durchschnitt des Wasserwertes der drei Versuche an.

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Auswertung - Frage 5

Dem Wasserwert des Kalorimeters entspricht eine Wärmekapazität C in J/°C. (Erinnerung: C = $c_{\mathrm{Wasser}} \cdot m_{\mathrm{Wasser}}$, c_{Wasser} = 4,2 J/(g·°C)). Wie groß ist hier die Wärmekapazität des Kalorimeters?

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