Mixture temperature and heat capacity of the calorimeter with Cobra SMARTsense

Physics	Thermodynamics	Calorimetry

Difficulty level	Group size	Preparation time	Execution time
medium	1	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6051dad41dbcea0003704baa

Teacher information

Application

Experimental set-up

This experiment deals with the mixing temperature and heat capacity of the calorimeter. Warm water is added to the calorimeter with water at room temperature.

This is to ensure that the contents of the calorimeter are as close to a uniform temperature as possible.

The temperature differences used can be kept small compared to the experiment version without Cobra SMARTsense, because the electronic temperature sensor has a better resolution than the student thermometers with alcohol filling.

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Other teacher information (1/3)

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Prior knowledge

Students should be familiar with the basic concepts of thermodynamics, such as temperature and the concept of energy transfer.

Scientific principle

In this experiment, quantities of water at different temperatures are mixed together in a calorimeter.

The temperature development of the system is then observed and statements are made about the mixing temperature and the heat capacity of the calorimeter.

Other teacher information (2/3)

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Learning objective

Students learn how the mixing temperature of two liquids changes over time.

Tasks

Heat up different amounts of water with the butane burner and determine their temperature.

Then mix them to a known amount of water in the calorimeter, the temperature of which you have already determined.

Measure the mixture's temperature that occurs in the calorimeter.

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Other teacher information (3/3)

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Notes on structure and procedure

- When heating the water, the temperature curve does not have to be recorded so that the relevant measurements are not lost in a long measurement curve but remain clearly visible.
- Large temperature differences lead to large measuring errors here - it is recommended that all parts and the supply water are at (consistent) room temperature. The water does not need to be heated too much.
- The maxima of the temperature curve are evaluated as relevant temperature values - to make them clearly visible, the sensor is cooled in between.

Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Student Information

Motivation

Coffee with milk

Quantities of heat are distributed in such a way that eventually all parts in contact with each other have the same temperature.

If the heat capacities and initial temperatures are known, the final temperature can thus be predicted. Conversely, the heat capacity can be inferred from the final temperature if the initial temperatures are known.

We often encounter a mixture of liquids in everyday life: coffee and milk. In order to get a feeling for the temperature of different mixtures, among other things, we conduct the following experiment.

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Tasks

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The experimental setup

What is the temperature in the calorimeter when water of different temperatures is mixed?

Heat different amounts of water with the butane burner and determine their temperature.

Then mix them to a known amount of water in the calorimeter, the temperature of which you have already determined. Measure the temperature of the mixture in the calorimeter.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - Temperature, - 40 ... 120 °C (Bluetooth)	12903-00	1
2	Support base, variable	02001-00	1
3	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
5	Boss head	02043-00	2
6	Glass tube holder with tape measure clamp	05961-00	1
7	Ring with boss head, i. d. = 10 cm	37701-01	1
8	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
9	Universal clamp	37715-01	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 flask, borosilicate, wide neck, 250 ml	46152-00	1
14	Beaker, Borosilicate, low form, 250 ml	46054-00	1
15	Beaker, Borosilicate, low-form, 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
20	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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Set-up (1/2)

For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** is required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check that on your device (smartphone, tablet, desktop PC) **Bluetooth** is **activated**.

iOS

Android

Windows

Set-up (2/2)

Figure 1

1. Before starting the experiment, fill a storage vessel with water (0.5 to 1 l, e.g. a beaker 1000 ml, 36008-00) which has room temperature and is at the same temperature as the other setup material.

2. Assemble a heat-insulating vessel (calorimeter) from two beakers (250 ml and 400 ml) and two felt plates.

3.Push the stirring rod from below through the fitting hole in the lid.

4.Set up the tripod according to Fig. 1.

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Procedure (1/6)

1. Turn on your Cobra SMARTsense Temperature Sensor. Open the measure\ app and select the temperature sensor.

2. Set the sampling rate to 1 Hz.

3. Measure 50 ml of water from the Erlenmeyer flask in the measuring cylinder (exact measurement with the aid of the pipette) and fill it into the calorimeter. Note the amount of water $m_{\mathrm{Wasser,\,Kal}}$.

4. Place the lid with the stirring rod onto the calorimeter and insert the temperature sensor through a suitable hole in the lid so that it is immersed in the water but does not touch the groung.

5. Stir and wait until the temperature reading remains constant. Note the initial temperature in the calorimeter $\vartheta_{\mathrm{Kal,\,1}}$.

Procedure (2/6)

6. Measure 150 ml of water in the measuring cylinder and fill it into the Erlenmeyer flask. Note the amount of water $m_{\mathrm{Wasser,\,Erl}}$

7. Heat up the water with the burner by 15 to 25 °C.

8. Stop the heating, cool down the temperature sensor in the supply vessel.

9. Start the recording of the measurements in the measureApp , a measurement of the temperature is then recorded every second.

10. Measure the temperature in the Erlenmeyer flask with the temperature sensor until the reading remains constant.

11. Take the sensor out of the heated water and place it briefly in the storage vessel so that it cools down.

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Procedure (3/6)

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12. Fill the heated water into the calorimeter, put on the lid and push the temperature sensor back into the water through the hole in the lid.

13. Stir the water in the calorimeter carefully during the measurement so that the heat is distributed evenly.

14. Stop the measurement when the temperature slowly drops. Then save the measurement. The measurement can be reloaded and analyzed at any time under "my measurements".

15. Pour away the water from the calorimeter, dry the vessel of the calorimeter.

Procedure (4/6)

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16. Proceed in the same way for experiment 2 and 3.

For experiment 2, first fill the calorimeter with 100 ml of water from the storage vessel and heat 100 ml of water in the Erlenmeyer flask.

For experiment 3, fill the calorimeter with 150 ml of water from the storage vessel and heat up 50 ml of water in the flask.

17. Select the "Measure" tool in measureApp to evaluate the maxima of the measurement curves. The first maximum equals to the temperature of the heated water in the Erlenmeyer flask, $\vartheta_{\mathrm{Erl,\,1}}$.

The second maximum equals to the temperature of the mixture in the calorimeter $\vartheta_{\mathrm{Kal,\,2}}$.

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Procedure (5/6)

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18. The water from the Erlenmeyer flask cools down by the temperature difference $\Delta\vartheta_{\mathrm{Erl}}$ while the water in the calorimeter heats up by the temperature difference.

For the temperature differences applies:

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

$$\delta\vartheta_{\mathrm{cal}} = \vartheta_{\mathrm{cal,\,2}} - \vartheta_{\mathrm{cal,\,1}}$$

Procedure (6/6)

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19. Provided that no heat is released to the environment and no other heating sources are effective, the total amount of heat is maintained:

The heat quantity ΔQ_{Erl} emitted by the hot water is therefore equal to the quantity of heat ΔQ_{cal} absorbed by the cold water in the calorimeter (assuming that only the water is relevant):

$$\Delta Q_{\mathrm{Erl}} = c_{\mathrm{water}} \cdot m_{\mathrm{water,Erl}} \cdot \Delta\vartheta_{\mathrm{Erl}}$$

$$\Delta Q_{\mathrm{cal}} = c_{\mathrm{water}} \cdot m_{\mathrm{water,\,cal}} \cdot \Delta\vartheta_{\mathrm{cal}}$$

From (1) and (2) the mass of the water can be calculated according to

$$m_{\mathrm{water,\,cal}} = m_{\mathrm{water,\,Erl}} \cdot \frac{\Delta\vartheta_{\mathrm{Erl}}}{\Delta\vartheta_{\mathrm{cal}}}$$

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Report

Task 1

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Fill in your readings in this table.

Experiment 1	$m_{\text{water, cal}}$ / g	50	$\vartheta_{\text{cal, 1}}$ / °C		$\vartheta_{\text{cal, 2}}$ / °C	
	$m_{\text{water, Erl}}$ / g	150	$\vartheta_{\text{Erl, 1}}$ / °C			
Experiment 2	$m_{\text{water, cal}}$ / g	100	$\vartheta_{\text{cal, 1}}$ / °C		$\vartheta_{\text{cal, 2}}$ / °C	
	$m_{\text{water, Erl}}$ / g	100	$\vartheta_{\text{Erl, 1}}$ / °C			
Experiment 3	$m_{\text{water, cal}}$ / g	150	$\vartheta_{\text{cal, 1}}$ / °C		$\vartheta_{\text{cal, 2}}$ / °C	
	$m_{\text{water, Erl}}$ / g	50	$\vartheta_{\text{Erl, 1}}$ / °C			

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Task 2

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Fill in this table using the formulas defined in the procedure.

	ϑ_{Erl} / °C	ϑ_{cal} / °C	$m_{\mathrm{water,\,cal}}$ / g
Experiment 1			
Experiment 2			
Experiment 3			

Task 3

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There seems to be a discrepancy between the values determined in Task 1 and the values calculated in Task 2? Why?

- Strong heating changes the mass of water. The more the water is heated, the more its mass decreases.
- The water evaporates in very large quantities during the experiment, sufficient to explain the difference between the two values.
- The heat capacity of the calorimeter was neglected in the calculated value. However, in the execution it influences the measured values.
- When the two liquids are mixed, a relevant part of the water remains on the surface of the Erlenmeyer flask.

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Task 4

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Drag the words into the correct gaps

The ______ between the calculated value for the amount of water and the actual amount of water is called the ______ of the calorimeter.
The ______ C of the calorimeter corresponds to its water value.
This must be taken into account as an ______ in all experimental setups.

- difference
- heat capacity
- water value
- influence factor

Check

Task 5

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Type in the average of the water value of the three experiments and thus also the heat capacity of the calorimeter: ______

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Task 6

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Drag the words into the correct boxes!

When two liquids ______, the average faster particles of the warmer ______ collide with the average slower particles of the other liquid. Since a ______ always strives for the state of least ______, kinetic energy is released on contact. This distributes the ______ and the temperatures gradually adjust.

particle

mix

energy

heat

liquid

Check

Slide	Score / Total
Slide 22: Heat quantity	0/1
Slide 23: Calorimeter	0/4
Slide 25: Energy	0/5

Total 0 / 10

Solutions Repeat Export text

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