Teacher packs in Experimental Science

PHY Pack 10

Determination of the specific heat capacity of a solid by the method of mixtures

Pack contents:

A. Teacher's Guide
B. Students Guide
C. Assessment – Student's sheet
D. Extensions to experiments
E. Links to other packs
F. Health and Safety

Curriculum areas covered:

Heat energy

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Title: Determination of the specific heat capacity of a solid by the method of mixtures

Target group: Diploma in Basic Education Students

Also suitable for: B.Ed. (Basic Education)

Duration of Activity: 50 minutes plus discussion time

Learning outcomes:

At the end of the lesson the student should be able to

1. Knowledge and Understanding (KN)	KN1	State the SI units of specific heat capacity.
	KN2	Define heat capacity and specific heat capacity.
	KN3	Explain the function of the calorimeter in the experiment
2. Cognitive Skills (CS)	CS1	Identify the appropriate instruments for measuring the specific heat capacity of a substance.
	CS2	Explain the direction of heat transfer.
	CS3	Explain the mode of heat transfer in the experiment.
3. Key Skills (KS)	KS1	Set up the experiment as shown in the schematic diagram provided
	KS2	Obtain thermal equilibrium of the mixtures
	KS3	Take correct reading on the thermometer
	KS4	Take measures to reduce heat loss in heat experiments
4. Practical Skills (PS)	PS1	Make and record observations
	PS2	Tabulate results, perform calculation and write your conclusion

A. Teacher's Guide

Overview

Students are asked to find the specific heat capacity of a metal ball and are provided with the following apparatus:

- Solid (e.g. metal ball) of reasonable size
- Calorimeter with an insulated outer jacket and stirrer
- Thermometer (reading up to 0.1^{o}C)
- Heater
- Thread
- Sensitive balance
- Beaker

Aim

This experiment is to enable students to see how experimental data can be used to establish relationships among measured quantities, and use the relationship to make predictions outside the range of direct measurement.

Practical Skills to be developed

1. Application of scientific method including observation, measuring, collection, recording and tabulating data.
2. Use of significant figures.
3. Setting up apparatus for experiment.
4. Change of subject in given equations.
5. Team work and oral communication.

Advice to Tutor

A. Measured quantities should be repeated and averaged
B. Encourage student to do independent work, one at a time if in groups.
C. The calorimeter should be kept in its insulating jacket.
D. Thermal equilibrium should be achieved before the final temperature is taken.
E. Create time to discuss the theory behind the experiment.

Sample Assessment Questions with Answers

1. Define heat capacity and specific heat capacity of a substance. (KN2)

> **Answer:** Heat capacity is the quantity of heat required to change the temperature of a body by one degree. It is expressed in joule per kelvin (J/K) in S I units.
>
> Specific heat capacity is the quantity of heat required to change the temperature of one kilogram of a body by one degree. It is expressed in joule per kilogram per kelvin (Jkg^{-1} K^{-1}) in S I units.

2. Why is it important to transfer the hot metal ball quickly into the calorimeter as required in the experiment? (KS4)

Answer: To minimize heat loss to the environment.

3. Why is it necessary to hold the metal ball briefly in the steam above the boiling water? (KS2)

Answer: Two reasons-:

(i). To allow the water on the metal ball to drop and

(ii). To maintain constant temperature with the steam.

4. What mode of heat transfer takes place in this experiment? (CS3)

Answer: Heat transfer is mainly by conduction.

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B. Student Guide

Purpose

To determine the specific heat capacity of a solid by the method of mixtures

Background

The **heat capacity** C of an object (e.g. metal ball) is the proportionality constant between an amount of heat and the change in temperature that the heat produced in the object. Thus, $Q = C(T_f - T_i)$, where T_i and T_f are the initial and final temperatures of the object. Two objects made of the same material, say marble, will have heat capacities proportional to their masses. It is therefore convenient to define a "heat capacity per unit mass" or specific heat c that refers not to an object but to unit mass of the material of which the object is made and is expressed in joule per kilogram per Kelvin (J $kg^{-1}K^{-1}$). The specific heat capacity equation then becomes $Q = mc(T_f - T_i)$, where m is the mass of the object.

Equipment/ Materials/ Apparatus

You are provided with the following:

- Solid (e.g. metal ball) of reasonable size
- Calorimeter with an insulation, outer jacket and stirrer
- Thermometer (reading up to 0.1^{o}C)
- Heater
- Thread
- Sensitive balance
- Beaker

You are to determine the specific heat capacity of the metal ball.

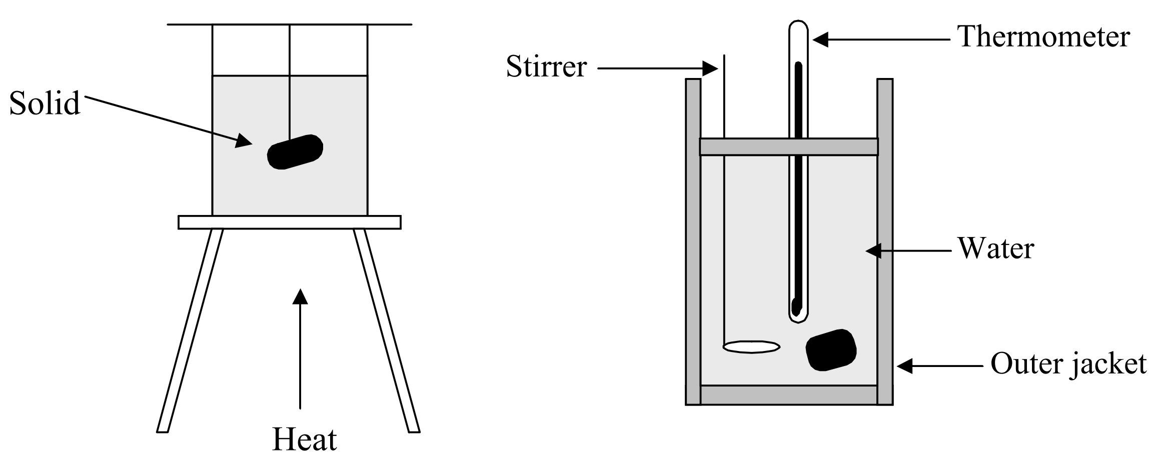

Figure 1: Experimental Setup for determining the specific heat capacity of a metal ball.

Instructions:
Water should be collected and placed near calorimeter 1hour before the experiment in order to ensure the same temperature.

1. You will work on individual basis. However, if the apparatus are not enough, then you will work in small groups.
2. You should set up the experiment as shown in the diagram above.
3. Weigh the metal ball and record its mass.
4. You should suspend the metal ball in water contained in a beaker
5. You should heat the beaker with the water until it boils for about 15 minutes.
6. While heating the solid, weigh the calorimeter empty, and record the mass.
7. Weigh the calorimeter again when two-thirds full of water, and record the mass.
8. Take the temperature of the water in the calorimeter placed in its outer jacket.
9. When the solid has been in the boiling water for about 15 minutes, you should remove it gently, hold it briefly in the steam above the water and quickly transfer it into the water in the calorimeter.
10. You should stir continuously and record the final temperature of the mixture.
11. Record your observations and calculate the specific heat capacity of the metal ball.
12. Record your observations as follows:

i.	Mass of solid	m_1	=
ii.	Mass of empty calorimeter	m_2	=
iii.	Mass of calorimeter + water	m_3	=
iv.	Initial temperature of water in calorimeter	T_i	=
v.	Temperature of the hot solid	100 ^{o}C	=
vi.	Temperature of mixture	T_f	=
vii.	Rise in temperature of water and calorimeter	$(T_f - T_i)\,^o$C	=
viii.	Fall in temperature of hot solid	(100- T_i) ^{o}C	=

13. Calculate the specific heat capacity c of the solid as show below:

Let S.H.C of solid	=	c
Also, let S.H.C of calorimeter	=	c_1
And let S.H.C of water	=	c_w
Heat lost by solid	=	$m_1 c(100 - T_f)$
Heat gained by water	=	$(m_3 - m_2)c_w(T_f - T_i)$
Heat gained by calorimeter	=	$m_2 c_1(T_f - T_i)$
Total heat gained	=	$(T_f - T_i)[(m_3 - m_2)c_w + m_2 c_1]$

But heat lost = Heat gained

$$m_1 c(100 - T_f) = (T_f - T_i)[(m_3 - m_2)c_w + m_2 c_1]$$

$$c = \frac{(T_f - T_i)[(m_3 - m_2)c_w + m_2 c_1]}{m_1(100 - T_f)}$$

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Conclusion

The specific heat capacity of the object = …….

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C. Assessment – Student's sheet

On completion of the experiment, you should answer the following questions:

1. Define heat capacity and specific heat capacity of a substance. (KN2)

2. Why is it important to transfer the hot metal ball quickly into the calorimeter as required in the experiment? (KS4)

3. Why is it necessary to hold the metal ball briefly in the steam above the boiling water? (KS2)

4. What mode of heat transfer takes place in this experiment? (CS3)

D. Extensions to experiment

1. A similar procedure can be used to determine the specific heat capacity of liquids.

E. References and Other Useful Links

1. Abbot A. F. (1980), *Ordinary Level Physics*, 3rd Edition, Heinemann Books International, London.

2. Nelkon M. and Parker P., (1987), *Advanced Level Physics*, Heinemann Educational Publishers, London.

3. Moss G. L. (1963), *Ordinary Level Practical Physics*, Heinemann Books International, London.

F. Health and Safety

1. When boiling the metal ball, be careful you do not spill the hot water on your skin and do not handle the hot metal ball in your palm.