

# Experiment 4

## Specific Heat of Solids

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### Synopsis

In this experiment we measure (add try to measure) the specific heat capacity of solids.

## I. THEORY AND PROCEDURE

### A. Apparatus

- Calorimeter
- Shots of material(s)
- Weighing balance
- Steam chamber
- Steam generator
- Electric heater
- Thermometers

### B. Theory

The change in temperature  $\Delta T$  of a material when supplied with a fixed amount of heat  $\Delta Q$  depends on the type of material and is inversely proportional to the mass  $m$  of the material. The material dependence is given the quantity called the specific heat  $c$  of the substance. The interdependence of these quantities is summarised by the equation

$$\Delta Q = cm\Delta T$$

The amount of heat required to raise the temperature of a unit mass of a substance by  $1^\circ\text{C}$  is called the specific heat of the substance. The SI unit of specific heat is  $[\text{J kg}^{-1} \text{K}^{-1}]$ . The specific heat of water is among the highest of all substances. Historically the specific heat of water is arbitrarily set as  $1\text{g}^{-1}^\circ\text{C}^{-1}$ . The equivalent SI value is  $4184 \text{J kg}^{-1} \text{K}^{-1}$ . A related quantity is the molar specific heat  $c_m$ , which is the specific heat for 1 mol of a substance.

If  $c_s$  is the heat capacity of shots,  $\Delta T_s \equiv T_f - T_s$  is the change in temperature of shots and  $m_s$  is the mass of shots then the heat lost by the shots is

$$\Delta Q_s = c_s m_s \Delta T_s$$

Similarly, heat gained by the water is

$$\Delta Q_w = c_w m_w \Delta T_w$$

with  $c_w$ ,  $m_w$ ,  $T_w$  and  $\Delta T_w$  have their proper meanings.

Now if there is no heat absorbed by the calorimeter then  $\Delta Q_w = \Delta Q_s$ , but that is not the case. To make the equation equal we replace  $m_w$  by  $m_w + m_f$  where  $m_f$  is the equivalent water mass of the calorimeter. Hence we get

$$c_s = \frac{c_w(m_w + m_f)\Delta T_w}{m_s \Delta T_s} \quad (1)$$

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### C. Procedure

First we measure the mass of the shots of each material. Then we place shots of material into the steam chamber and close them using a cork with hole through which we put a thermometer to measure the  $T_s$ . When the temperature reaches equilibrium, we turn the chamber over and quickly pour all the material into calorimeter with measured mass and temperature of water. We stir it using a different thermometer and measure the equilibrium temperature  $T_f$ .

We repeat this same procedure for different materials and then to measure  $m_f$  of the calorimeter, we put water of higher temperature  $\theta_{i1} \approx 60^\circ\text{C}$  into room temperature water inside calorimeter and measuring the equilibrium temperature  $\theta_f$ ; using the same principle:

$$m_f = \frac{m_1 \Delta\theta_1 - m_2 \Delta\theta_2}{\Delta\theta_2} \quad (2)$$

## II. OBSERVATIONS

Material	$m_s(\text{g})$	$m_w(\text{g})$	$T_w(^{\circ}\text{C})$	$T_f(^{\circ}\text{C})$
Copper	100.1	90.0	23.5	30.1
Acrylic	44.5	45.0	24.9	35.0
Copper <sup>a</sup>	183.5	52.0	23.0	39.1
Ceramic	31.4	69.0	23.9	29.3

<sup>a</sup> Took the copper out earlier then equilibrium temperature

**TABLE I.** With calorimeter of type-1, data was taken on 23 Jan 2025

Data for Type 1:  
 $m_2 = \{ T_2 = m_1 \text{ g } T_1 \quad T_f$

Material	$m_s(\text{g})$	$m_w(\text{g})$	$T_s(^{\circ}\text{C})$	$T_w(^{\circ}\text{C})$	$T_f(^{\circ}\text{C})$
Copper	55.0	176.4		26.1	30.0
Copper <sup>a</sup>	171.1	154.0	90–91	25.1	31.2
Acrylic	52.3	144.4	87–88	25.1	29.3
Ceramic	39.6	132.4	80	24.8	28.6
Copper	180.0	180.0		22.3	28.5

<sup>a</sup> Spillage while pouring water

**TABLE II.** With calorimeter of type-2, data taken on 29 Jan 2025

Data for Type 1:  
 $m_2 = \{ T_2 = m_1 \text{ g } T_1 \quad T_f$

## III. UNCERTAINTIES AND SOURCES OF ERROR

The experimental uncertainties originate from the following sources:

### A. Uncertainties from precision of instrument

- Weight Measurement: All weight values have an uncertainty of  $\Delta m = \pm 0.05 \text{ g}$  due to instrument resolution.
- Temperature Measurement: Temperature values have an uncertainty of  $\Delta T = \pm 0.005 \text{ K}$  due to instrument resolution.
- Mercury Thermometer: Thermometer used to measure  $T_s$  has an uncertainty of  $\Delta T = \pm 0.5 \text{ K}$

### B. Systematic Errors

- Spillage during pouring of water

- Material being left in container
- Material going out of calorimeter
- material radiating heat as per newtons law of cooling
- all equipment is giving proper values assumption
- unequal temperature of calorimeter after each run if not calibrated
- uneven heating

#### **Precautions**

- if a material is already used then we preheat it to remove water
- if some error occurs during experiment then we repeat to replace the data point.
- we pour tap water in calorimeter after each run to make the temperature constant.

Explain error analysis of the following code in latex in this way: Section of error analysis  
Subsection for each parameter and its error propagation

### **IV. CALCULATION AND ERROR ANALYSIS**

Since the voltage is spread across a noticeable range we take the mean value of minimum and maximum voltage to reduce the uncertainty of voltage and current. We shall take the ?? as the data points. Calculating the averages from ?? we get:

#### **A. Reduced Current Uncertainty**

After taking mean, the new uncertainty in  $A$  is determined by

$$\Delta A = \Delta A \left( \frac{V_{max} - V_{min}}{\Delta V} \right)$$

#### **B. Error Propagation**

##### **1. Resistance Calculation**

The resistance  $R = V/I$  has uncertainty given by:

$$\frac{\Delta R}{R} = \sqrt{\left( \frac{\Delta V}{V} \right)^2 + \left( \frac{\Delta I}{I} \right)^2} \quad (3)$$

### C. Result

??

The reference resistance was determined to be:  $R_0 = 2.90 \pm 7.7\%$ . (This error accounts for uncertainty in temperature measurements)

The Stefan-Boltzmann fit for the tungsten filament showed:

$$P = (4.00 \pm 0.066) \times 10^{-14} \text{ T}^4$$

The log-log analysis revealed a power-law relationship:

$$\log P = (3.98 \pm 0.06) \log T + (-30.71 \pm 0.48)$$

The measured slope of  $m = 3.98 \pm 0.06$  agrees with Stefan's law prediction of  $P \propto T^4$ , as the theoretical value of 4 lies within the experimental uncertainty range.

### Appendix A: Equipment Faulty

This same experiment was performed on 22 January 2025, whose observations didn't align with Stefan's law. Subsequent investigation revealed the apparatus used during that trial had faulty calibration.

### Appendix B: Ambient Temperature

No measure of ambient temperature is taken in the latter experiment, since it had no use in calculations other than the fact that it can be neglected.