

First name

Date

Last name

Degree program name

Experiment 427

Determination of the specific heat of a liquid using an electrocalorimeter

Tested liquid type:		Measurement I	Measurement II
Calorimeter weight I, m_{k1}	[kg]		
Calorimeter weight II, m_{k2}	[kg]		
Calorimeter weight I. with water, m_1	[kg]		
Calorimeter weight II. with tested liquid, m_2	[kg]		
Mass of water, $m_w = m_1 - m_{k1}$	[kg]		
The mass of the liquid, $m_x = m_2 - m_{k2}$	[kg]		
Initial temperature of the calorimeter I and water t_{01}	[°C]		
Initial temperature of the calorimeter II and the tested liquid t_{02}	[°C]		
End temperature of the calorimeter I and water t_1	[°C]		
End temperature of the calorimeter II and tested liquid, t_2	[°C]		
Specific heat of the calorimeter, c_k	[J/(kg·K)]	900	
Specific heat of water c_w	[J/(kg·K)]	4190	
Specific heat of the liquid c_x	[J/(kg·K)]		
Average specific heat of the liquid c_c	[J/(kg·K)]		
Absolute error Δc_c	[J/(kg·K)]		
Relative error B_p	[%]		

427. Determination of the specific heat of a liquid using an electrocalorimeter

Introduction

When two or more bodies of different temperature come into contact, heat flows from the warmer body to the colder body. The body that gives off heat lowers its temperature, and the body that absorbs - increases it. Heat is, therefore, a form of energy transferred from one body to another. Temperature is a measure of the thermal state of the body.

The amount of heat Q is expressed in the SI system in joules [J], while the temperature T - in Kelvin [K]. In everyday life, temperature is measured in degrees Celsius [$^{\circ}\text{C}$] and in this case we denote it with a lower case t . The relationship between both scales (Kelvin and Celsius) is shown by the equation

$$T = t + 273,15.$$

However the temperature increase is the same in both scales: $\Delta T = \Delta t$.

The amount of heat Q taken when the body is heated from temperature T_1 to temperature T_2 (or the heat given off when the body cools from T_2 to T_1) depends on the type of body and is proportional to its mass m and the temperature change:

$$Q = c \cdot m \cdot \Delta T.$$

The proportionality factor c is called the average specific heat in the temperature range from T_1 to T_2 . From (1) we obtain the formula defining the specific heat:

$$c = \frac{Q}{m \cdot \Delta T}.$$

Specific heat is the amount of heat required to warm a unit of body by a unit of temperature. The specific heat is expressed in J/(kg·K).

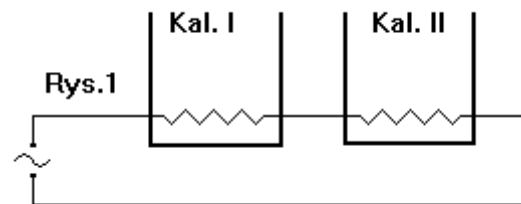
If we provide two bodies with specific heat c_w i c_x the same amount of heat ΔQ , then we obtain the relationship:

$$\Delta Q = m_w \cdot c_w \cdot \Delta t_w = m_x \cdot c_x \cdot \Delta t_x \quad (1)$$

Knowing the masses of both bodies, their temperature increases and the specific heat c_w of one of these bodies (water), we can determine the specific heat c_x of the other body. This idea was used to determine the specific heat of a liquid using an electrocalorimeter.

Equal amounts of heat are supplied to different liquids via electrically heated coils of equal resistance connected in series (Fig. 1) to an alternating current source. The amount of heat ΔQ_d released over time τ in the conductor with resistance R , through which the current of intensity I flows, is equal to the work of the electric current

$$\Delta Q_d = I^2 \cdot R \cdot \tau. \quad (2)$$



Since the current I flows through the same coils at the same time, the amounts of heat released therein must be equal to each other. The heat absorbed by the calorimeters should also be taken into account, which gives rise to the heat balance equation:

$$(m_w c_w + m_{k1} c_k) (t_1 - t_{01}) = (m_x c_x + m_{k2} c_k) (t_2 - t_{02}), \quad (3)$$

where:

m_w, c_w — mass, specific heat of water; m_x, c_x — mass, specific heat of the test liquid; m_{k1}, m_{k2}, c_k — mass of calorimeters and specific heat of the material from which they are made;

t_1, t_{01}, t_2, t_{02} — end and initial temperature values of the calorimeter with water and test liquid.

By transforming the equation (3), we obtain the formula from which the unknown specific heat c_x of the tested liquid can be determined.

$$c_x = \frac{(m_w c_w + m_{k1} c_k) (t_1 - t_{01}) - m_{k2} c_k (t_2 - t_{02})}{m_x (t_2 - t_{02})} \quad (4)$$

Performance of the task

1. We weigh the inner vessels of the calorimeters (metal parts) – mass: m_{k1}, m_{k2} .
2. We fill half of one calorimeter with warm water and the other half with the tested liquid (e.g. glycerine) and weigh it — mass: m_1, m_2 . We calculate the mass of water $m_w = m_1 - m_{k1}$ and the mass of the tested liquid $m_x = m_2 - m_{k2}$.
3. We place the vessels in their covers, then insert the thermometers and connect the circuit as shown in Fig.1. We use 5 Ω Heaters. We keep the thermometers perpendicular so that they do not touch the heater.

4. We make a circular motion with the entire calorimeter.
5. We measure the initial temperature of water — t_{01} and the tested liquid — t_{02} .
6. We turn on the current on to the circuit and let it run (about 10 minutes) until the temperature of the tested liquid rises by about 10 °C. We set on the power supply 15 V - alternating current. During the experiment we mix liquids every 1 min. as in point 4.
7. After turning the electricity off and thoroughly stirring the liquid (as in point 4), we read the final temperature: water — t_1 , tested liquid — t_2 .
8. We take the lids with spirals out of the calorimeters and rinse the spirals with water.
9. We repeat the measurements, switching the covers with the spirals in places so that the spiral that previously heated the water now warms the tested liquid.
10. For both measurements we calculate the specific heat of the tested liquid, formula (4).
11. We find the average value of the specific heat and compare it with the table value (we calculate the absolute and relative error in relation to the table value).

Calculation of the uncertainties

We calculate the errors for a simplified formula for the specific heat of a liquid. We get it after crossing out the impact of calorimeters in the heat balance in formula (4).

It is justified by the fact that the calorimeter's heat capacity (it is the product of the mass and specific heat of the body) is less than 10% of the heat capacity of the tested liquid and about 5% of the heat capacity of the water used in the experiment.

This fact is caused by relatively low values of specific heat of metals and small masses of calorimeters.

Simplified formula for c_x is as follows:

$$c_x = \frac{m_w c_w (t_1 - t_{01})}{m_x (t_2 - t_{02})} = \frac{m_w c_w t_w}{m_x t_x} . \quad (5)$$

Physical quantities t_w , t_x denote the increase in the temperature of the water and the tested liquid, respectively.

The specific heat measurement error on the basis of formula (5) will be determined by the logarithmic differentiation method. We get the following expression for the maximum relative error:

$$\frac{\Delta c_x}{c_x} = \frac{\Delta m_w}{m_w} + \frac{\Delta m_x}{m_x} + \frac{\Delta t_x}{t_x} + \frac{\Delta t_w}{t_w} . \quad (6)$$

When deriving the formula (6), it was assumed that the following quantities are affected by a measurement error: m_w, m_x, t_x, t_w . If we weigh with the accuracy of Δm , then, due to double weighing, we must assume: $\Delta m_w = \Delta m_x = 2 \cdot \Delta m$. Similarly, $\Delta t_w = \Delta t_x = 2 \cdot \Delta t$, where Δt — accuracy of temperature measurement. We also calculate the absolute error Δc_x .