An experimental study on specific heat capacity

Aim

The aim of this experiment is to measure the specific heat capacity of a metal block and than being able to determine what metal is it.

Background information

Heat is the energy that is transferred from one body to another as a result of a difference in temperature to be able to reach thermal equilibrium, and the specific heat capacity, C, is the energy required to increase the temperature of a unit mass of the body by one Kelvin. Heat and specific heat capacity are related with the formula " **$Q = m * c * \Delta T$**". The water equivalent, so the product of the mass of a body by its specific heat equal numerically to the mass of water that is equivalent in thermal capacity to the body in question, must be calculated to know how much heat is lost to the calorimeter.

Instruments and materials

Instruments:
- Thermometer —> sensitivity ± 0.1°C ; range -10°C to 51°C
- Electric scale —> sensitivity ± 0.01 g ; range 0 g to 500 g

Materials:
- Electric heater
- Baker
- Adiabatic calorimeter

Figure 1 —> Heater with baker and metal on top

Safety issues

- Pay special attention when using the electric heater, the hot water and the metals to prevent burning yourself or damaging the equipment.

Procedure

Part 1: calculating the water equivalent mass
- Add approximately 200 ml of room temperature water to the baker and measure with the scale the exact mass and with the thermometer the exact temperature of it. To simplify the procedure place the baker on the electric scale at the beginning and tare it to zero before adding the water.
- Move all the water in the empty calorimeter and repeat the first step. To waste less time turn on the electric heater at this moment in the way to have it already heated afterwards.
- Instead of pouring the water again in the calorimeter, place the baker on top of the electric heater.
- With the thermometer keep an eye on the temperature of the water on the heater and wait for it to reach approximately 45°C before tuning of the heater and measuring both the precise temperature and mass of the water. This because the water will continue to heat up a bit more after being removed from the heater, and as the thermometer has a maximum measurable temperature of 50°C, if heated to 50°C, it would surpass it.
- Pour the hot water in the calorimeter, close the lid and immediately stir the water for a few seconds, to reach thermal equilibrium. Measure the equilibrium temperature
- Using the formula for the thermal equilibrium and the data collected, calculate the water equivalent mass and the uncertainty on this value


Figure 2 —> Calorimeter, scale and baker

Part 2: calculating the specific heat capacity of a metal
-Repeat the first step in part 1.
-Measure with the scale the exact mass of the piece of metal.
-Fill a baker with enough water to be able to submerge completely the piece of metal and place the piece of metal inside of it.
-Place the baker on top of the electrical heater and wait for the temperature of the metal block to reach a temperature of approximately 45°C before removing the baker from the heater.
-Stir the water to have a uniform temperature. Record the value for the temperature and then by using a hook carefully remove the metal block from the baker to put it inside the calorimeter.
-Close the lid and stir the water for a few seconds to reach thermal equilibrium inside the calorimeter, and measure the equilibrium temperature with the thermometer.
-Using the formula for the thermal equilibrium, calculate the specific heat capacity of the metal and its uncertainty, and then compare the value to the list of specific heat capacities of metals to try and recognise the type of metal used in the experiment.

Results

	Mass (g ; ± 0.01)	Temperature (° ; ± 0.1°)
Cold water part 1	209,88	+ 24.3
Hot water part 1	207,43	+ 48.2
Equilibrium temp. Part 1		+ 35.3
Cold water part 2	174,48	+ 24.5
Metal block	283,16	+ 46.8
Equilibrium temp. Part 2		+ 28.1

Analysis

$M_E = (M_H * T_H + M_C * T_C - (M_H + M_C) * T_{Eq}) / (T_{Eq} - T_C)$

$M_E = (207.43 * 48.2 + 209.88 * 24.3 - (207.43 + 209.88) * 35.3) / (35.3 - 24.3) = 33.4 \text{ g} \pm 4.47$

$C_M = (C_W * (M_W * M_E) + (T_{EQ} - T_W)) / (M_M * (T_M + T_{Eq}))$

$C_M = (4200 * (174.48 * 33{,}38) + (28.1- 24.5)) / (283.16 * (46.8 + 28.1)) = 594 \text{ J Kg}^{-1}\text{K}^{-1} \pm 123.7$

- When compared to the table with all the specific heat capacities, steel is the most probable material used in the experiment as it has a specific heat capacity of 510.78 J $Kg^{-1}K^{-1}$ and it is also a non-toxic and easily reparable material.

Conclusion

In conclusion it was possible to identify a possible metal which was used, even though the degree of accuracy of the measurements taken was too small leading to an uncertainty of ± 123.7 , which in this case is definitely too big as a value to be able to tell with certainty which type of metal was used. For this reason, it is preferable to have more accurate instruments in this type of experiment to be able to obtain a very precise answer. In this case the properties of steel fit very well as a result for this investigation, so increasing the chances for it to be the type of material used.

Bibliography

- Figure 1 —> Heater with baker and metal on top
- Figure 2 —> Calorimeter, scale and baker
- https://www.engineersedge.com/materials/specific_heat_capacity_of_metals_13259.htm