EXPERIMENT 17

AIM

To determine the specific heat capacity of a given (i) and solid (ii) a liquid by the method of mixtures.

APPARATUS AND MATERIAL REQUIRED

Copper calorimeter with lid, stirrer and insulating cover (the lid should have provision to insert thermometer in addition to the stirrer), two thermometers (0 °C to 100 °C or 110 °C with a least count of 0.5 °C), a solid, preferably metallic (brass/copper/steel/aluminium) cylinder which is insoluble in given liquid and water, given liquid, two beakers (100 mL and 250 mL), a heating device (heater/hot plate/gas burner); physical balance, spring balance with weight box (including fractional weights), a piece of strong non-flexible thread (25-30 cm long), water, laboratory stand, tripod stand and wire gauze.

PRINCIPLE / THEORY

For a body of mass m and specific heat s, the amount of heat Q lost/gained by it when its temperature falls/rises by Δt is given by

$$\Delta Q = ms\,\Delta t \qquad \text{(E 17.1)}$$

Specific heat capacity: It is the amount of heat required to raise the temperature of unit mass of a substance through 1°C. Its S.I unit is $\text{Jkg}^{-1}\,\text{K}^{-1}$.

Principle of Calorimetry: If bodies of different temperatures are brought in thermal contact, the amount of heat lost by the body at higher temperature is equal to the amount of heat gained by the body at lower temperature, at thermal equilibrium, provided no heat is lost to the surrounding.

(a) Specific heat capacity of given solid by method of mixtures

PROCEDURE

1. Set the physical balance and make sure there is no zero error.
2. Weigh the empty calorimeter with stirrer and lid with the physical balance/spring balance. Ensure that calorimeter is clean and dry.

Note the mass m_1 of the calorimeter. Pour the given water in the calorimeter. Make sure that the quantity of water taken would be sufficient to completely submerge the given solid in it. Weigh the calorimeter with water along with the stirrer and the lid and note its mass m_2. Place the calorimeter in its insulating cover.

3. Dip the solid in water and take it out. Now shake it to remove water sticking to its surface. Weigh the wet solid with the physical balance and note down its mass m_3.

4. Tie the solid tightly with the thread at its middle. Make sure that it can be lifted by holding the thread without slipping.

Place a 250 mL beaker on the wire gauze kept on a tripod stand as shown in the Fig. E 17.1(a). Fill the beaker up to the half with water. Now suspend the solid in the beaker containing water by tying the other end of the thread to a laboratory stand. The solid should be completely submerged in water and should be atleast 0.5 cm below the surface. Now heat the water with the solid suspended in it [Fig. E 17.1 (a)].

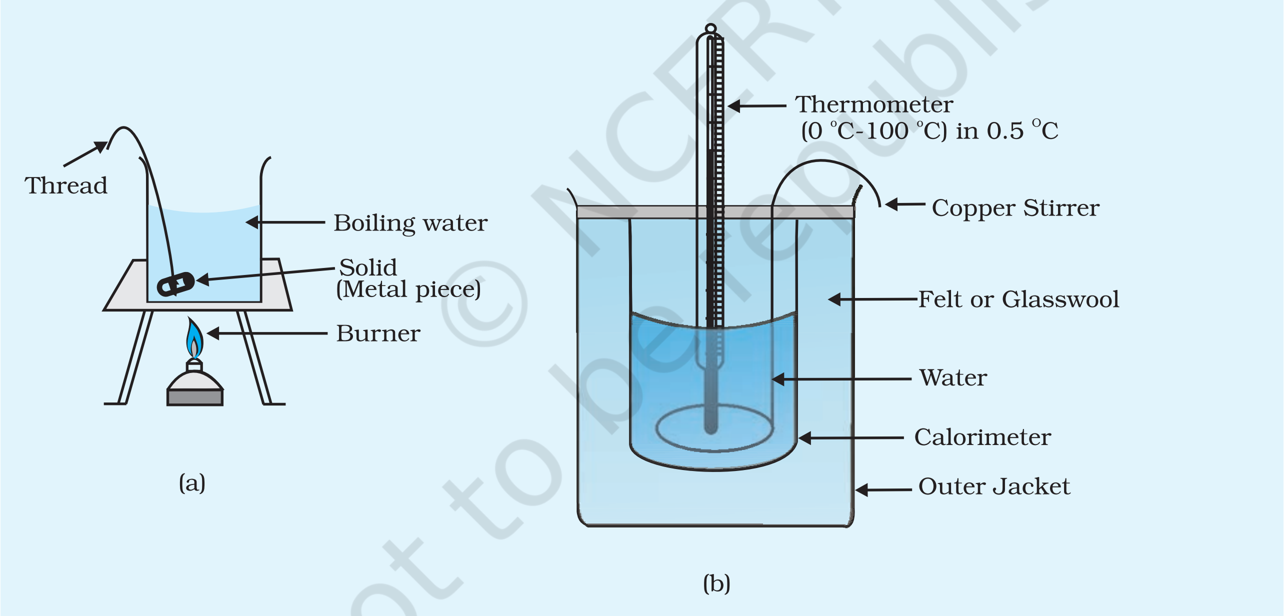

Fig. E 17.1: *Experimental setup for determining specific heat of a given solid*

5. Note the least count of the thermometer. Measure the temperature of the water taken in the calorimeter. Record the temperature t_1 of the water.

6. Let the water in the beaker boil for about 5-10 minutes. Now measure the temperature t_2 of the water with the other thermometer and record the same. Holding the solid with the thread tied to it,

remove it from the boiling water, shake it to remove water sticking on it and quickly put it in the water in the calorimeter and replace the lid immediately (Fig. E 17.1 (b)). Stir the water with the stirrer. Measure the temperature of the water once equilibrium is attained, that is, temperature of the mixture becomes constant. Record this temperature as t_3.

OBSERVATIONS

Mass of the empty calorimeter with stirrer (m_1) = ... g

Mass of the calorimeter with water (m_2) = ... g

Mass of solid (m_3) = ... g

Initial temperature of the water (t_1) = ... °C = ... K

Temperature of the solid in boiling water (t_2) = ... °C = ... K

Temperature of the mixture (t_3) = ... °C

Specific heat capacity of material of calorimeter s_1 = ... Jkg^{-1} $°C^{-1}$ (Jkg^{-1} K^{-1})

Specific heat capacity of water (s) = ... Jkg^{-1} K^{-1}

CALCULATIONS

1. Mass of the water in calorimeter ($m_2 - m_1$) = ... g = ... kg
2. Change in temperature of liquid and calorimeter ($t_3 - t_1$) = ... °C
3. Change in temperature of solid ($t_2 - t_3$) == ... °C

   Heat given by solid in cooling from t_2 to t_3.

   = Heat gained by liquid in raising its temperature from t_1 to t_3 + heat gained by calorimeter in raising its temperature from t_1 to t_3.

   $$m_3 s_o (t_2 - t_3) = (m_2 - m_1)\, s\, (t_2 - t_1) + m_1 s_1 (t_3 - t_1)$$

   $$s_o = \frac{(m_2 - m_1)\, s\,(t_2 - t_1) + m_1 s_1 (t_3 - t_1)}{m_3 (t_2 - t_3)} = \ldots \text{ J kg}^{-1}\,°\text{C}^{-1}$$

(b) Specific heat capacity of given liquid by method of mixtures

PROCEDURE

1. Set the phyiscal balance and make sure there is no zero error.
2. Weigh the empty calorimeter with stirrer and lid with the physical balance/spring balance. Ensure that calorimeter is clean and dry. Note the mass m_1 of the calorimeter. Pour the

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given liquid in the calorimeter. Make sure that the quantity of liquid taken would be sufficient to completely submerge the solid in it. Weigh the calorimeter with liquid along with the stirrer and the lid and note its mass m_2. Place the calorimeter in its insulating cover.

3. Take a metallic cylinder whose specific heat capacity is known. Dip it in water in a container and shake it to remove the water sticking to its surface. Weigh the wet solid with the physical balance and note down its mass m_3.

4. Tie the solid tightly with the thread at its middle. Make sure that it can be lifted by holding the thread without slipping.

   Place a 250 mL beaker on the wire gauze kept on a tripod stand as shown in Fig. E 17.1(a). Fill the beaker up to half with water. Now suspend the solid in the beaker containing water by tying the other end of the thread to a laboratory stand. The solid should be completely submerged in water and should be atleast 0.5 cm below the surface. Now heat the water with the solid suspended in it [Fig. E 17.1(a)].

5. Note the least count of the thermometer. Measure the temperature of the water taken in the calorimeter. Record the temperature t_1 of the water.

6. Let the liquid in the beaker boil for about 5-10 minutes. Now measure the temperature t_2 of the liquid with the other thermometer and record the same. Holding the solid with the thread tied to it remove it from the boiling water, shake it to remove water sticking on it and quickly put it in the liquid in the calorimeter and replace the lid immediately [Fig. E 17.1(b)]. Stir it with the stirrer. Measure the temperature of the liquid once equilibrium is attained, that is, temperature of the mixture becomes constant. Record this temperature as t_3.

OBSERVATIONS

Mass of the empty calorimeter with stirrer (m_1) = ... g

Mass of the calorimeter with liquid (m_2) = ... g

Mass of solid (m_3) = ... g

Initial temperature of the liquid (t_1) = °C = ... K

Temperature of the solid in boiling water (t_2) = °C = ... K

Temperature of the mixture (t_3) = °C = ... K

Specific heat capacity of material of calorimeter s_1 = ... Jkg^{-1} °C^{-1} (Jkg^{-1} K^{-1})

Specific heat capacity of solid (s_0) = ... Jkg^{-1} K^{-1}

CALCULATIONS

1. Mass of the liquid in calorimeter $(m_2 - m_1)$ = ... g = ... kg
2. Change in temperature of liquid and calorimeter $(t_3 - t_1)$ = ... °C
3. Change in temperature of solid $(t_2 - t_3)$ = ... °C

   Heat given by solid in cooling from t_2 to t_3.

   = Heat gained by liquid in raising its temperature from t_1 to t_3 + heat gained by calorimeter in raising its temperature from t_1 to t_3.

   $m_3 s_o (t_2 - t_3) = (m_2 - m_1)\, s\, (t_2 - t_1) + m_1 s_1 (t_3 - t_1)$

   $$s = \frac{m_3 s_0 (t_2 - t_3) - m_1 s_1 (t_3 - t_1)}{(m_2 - m_1)(t_2 - t_1)} = \ldots \text{ J kg}^{-1}\,{}^\circ\text{C}^{-1}$$

RESULT

(a) The specific heat of the given solid is ... Jkg^{-1} K^{-1} within experimental error.

(b) The specific heat of the given liquid is ... Jkg^{-1} K^{-1} within experimental error.

PRECAUTIONS

1. Physical balance should be in proper working condition and ensure that there is no zero error.
2. The two thermometers used should be of the same range and least count.
3. The solid used should not be chemically reactive with the liquid used or water.
4. The calorimeter should always be kept in its insulated cover and at a sufficient distance from the source of heat and should not be exposed to sunlight so that it absorbs no heat from the surrounding.
5. The solid should be transferred quickly so that its temperature is same as recorded when it is dropped in the liquid.
6. Liquid should not be allowed to splash while dropping the solid in it in the calorimeter. It is advised that the solid should be lowered gently into the liquid with the help of the thread tied to it.
7. While measuring the temperature, the thermometers should always be held in vertical position. The line of sight should be perpendicular to the mercury level while recording the temperature.

SOURCES OF ERROR

1. Radiation losses cannot be completely eliminated.
2. Heat loss that takes place during the short period while transferring hot solid into calorimeter, cannot be accounted for.
3. Though mercury in the thermometer bulb has low specific heat, it absorbs some heat.
4. There may be some error in measurement of mass and temperature.

DISCUSSION

1. There may be some heat loss while transferring the solid, from boiling water to the liquid kept in the calorimeter. Heat loss may also occur due to time lapsed between putting of hot solid in calorimeter and replacing its lid.
2. The insulating cover of the calorimeter may not be a perfect insulator.
3. Error in measurement of mass of calorimeter, calorimeter with liquid and that of the solid may affect the calculation of specific heat capacity of the liquid.
4. Calculation of specific heat capacity of the liquid may also be affected by the error in measurement of temperatures.
5. Even though the metal piece is kept in boiling water, it may not have exactly the same temperature as that of boiling water.

SELF ASSESSMENT

1. What is water equivalent?
2. Why do we generally use a calorimeter made of copper?
3. Why is it important to stir the contents before taking the temperature of the mixture?
4. Is specific heat a constant quantity?
5. What is thermal equilibrium?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

We can verify the principle of calorimetry, if specific heat capacity of the solid and the liquid are known.