Experiment - 9 : Specific heat capacity of a given (i) solid and (ii) liquid by method of mixtures.

Theory

When two substances at different temperatures are mixed, then heat is exchanged between them. The substance at higher temperature loses heat and the one at lower temperature gains heat till they come to an equilibrium temperature. This is the law of mixtures. The amount of heat lost by the hotter body equals to the amount of heat gained by the colder body provided (i) no heat is lost to the surroundings and (ii) the substances do not react chemically to produce or absorb heat. For a body of mass m, having a specific heat s, the amount of heat gained or lost ΔQ is given by

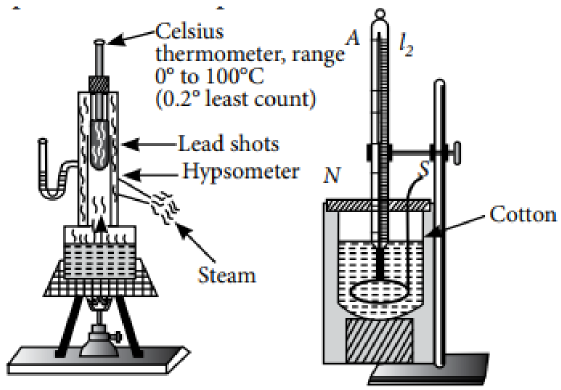
$\Delta Q = ms\, \Delta\theta$

where $\Delta\theta$ is the rise or fall in the temperature of the body

Procedure

Finding the specific heat of a solid (lead shots)

The experimental set up is as follows:



Lead shots are put in water in a test tube. The test tube is heated with steam in a vessel called the hypsometer. The temperature of lead shots is recorded. Parallely, cold water is taken in a calorimeter, with a thermometer to record its temperature.

After the lead shots are heated to a high temperature, they are quickly transferred to the calorimeter, and then the final temperature of the mixture is recorded. Let m_s , m_w and m_c be the masses of solid (lead), water and calorimeter respectively, θ_s , θ_w and θ_e be the temperature of solid (lead) when heated, temperature of water in the calorimeter initially and equilibrium temperature of the mixture finally.

Using, Heat lost = Heat gained

$m_s \cdot s_s \cdot (\theta_s - \theta_e) = (m_w \cdot s_w + m_c \cdot s_c)(\theta_e - \theta_w)$

where s_s, s_w and s_c are the specific heats of the solid, water and calorimeter. From the above equation s_s is determined.

Often the

$$m_c \cdot \left(\frac{s_c}{s_w}\right)$$

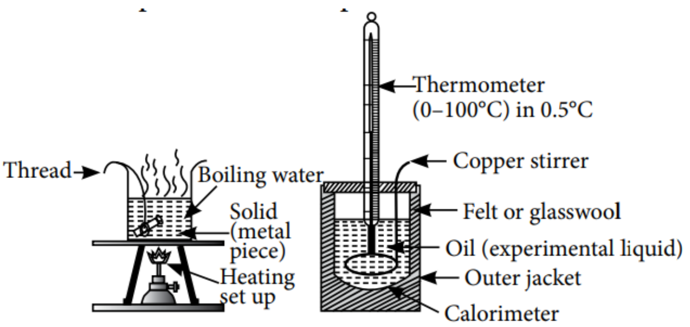
is known as the water equivalent of the calorimeter and is denoted by w. So, the above equation is written as

$m_s \cdot s_s (\theta_s - \theta_e) = (m_w + w) \cdot s_w (\theta_e - \theta_w)$

The calorimeter is designed to minimize heat losses.

Finding the specific heat of a given liquid (kerosene or turpentine oil)

Now, the experimental set up is as follows:



As compared to the previous experiment, here instead of lead shots, we are heating a metal piece of known specific heat and the liquid whose specific heat is to be found out is taken in the calorimeter. So, the water is replaced by the liquid.

Here, after heating the solid, it is quickly transferred into the calorimeter containing the liquid. At thermal equilibrium

$m_s \cdot s_s (\theta_s - \theta_e) = (m_l \cdot s_l + m_c \cdot s_c)(\theta_e - \theta_l)$

where the subscript l stands for the liquid. Thus, s_l can be determined.

MCQs Corner

Experiment – 9

38. In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 150°C. Immediately, it is put into water of volume 150 cc at 27°C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 40°C. The specific heat of aluminium is (take 4.2 joule = 1 calorie)

(a) 315 J/kg-°C (b) 378 J/kg-°C (c) 476 J/kg-°C (d) 434 J/kg-°C

39. The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C respectively. The temperature when A and B are mixed is 16°C and when B and C are mixed is 23°C. The temperature when A and C are mixed is

(a) 18.5°C (b) 20.3°C (c) 21.6°C (d) 23.25°C

40. The temperature of 100 g of water is to be raised from 24°C to 90°C by adding steam to it. The mass of the steam required for this purpose is : (Latent heat of vaporization for steam is 540 cal/g)

(a) 8 g (b) 10 g (c) 12 g (d) 14 g

41. If 1 g of ice at 0°C is added to 5 g of water at 10°C. If the latent heat of ice is 80 cal/g, the final temperature of the mixture is

(a) 5°C (b) 0°C (c) –5°C (d) none of these

42. 200 g of a solid ball at 20°C is dropped in an equal amount of water at 80°C. The resulting temperature is 60°C. This means that specific heat of solid is

(a) one-fourth of water

(b) one-half of water

(c) twice of water

(d) four times of water

Answer Key

38. (d) 39. (b) 40. (c) 41. (b) 42. (b)

Hints & Explanation

38. (d) : Let S be the specific heat of aluminium.
By principle of calorimetry, $Q_{Given} = Q_{used}$
Heat capacity of water = 1 cal/g-°C
$200 \times S \times (150 - 40) = 150 \times 1 \times 1 \times (40 - 27) + 25 \times 1 \times (40 - 27)$ $200 \times S \times 110 = 150 \times 13 + 25 \times 13$

$$S = \frac{13 \times 175}{200 \times 110} = 0.1034 \text{ cal/g-°C} = 103.4 \times 4.2 \text{ J/kg-°C}$$
$$= 434 \text{ J/kg-°C}$$

39. (b) : When A and B are mixed,
heat lost by B = Heat gained by A.

$$ms_B(19 - 16) = ms_A(16 - 12) \Rightarrow s_A = \frac{3}{4}s_B$$

Similarly, when B and C are mixed,

$$ms_B(23 - 19) = ms_c(28 - 23) \Rightarrow s_C = \frac{4}{5}s_B$$

Mixing A and C yields,
$ms_A(T - 12°) = ms_c(28 - T)$
$$\Rightarrow m\left(\frac{3}{4}s_B\right)(T - 12) = m\left(\frac{4}{5}s_B\right)(28 - T)$$
$\Rightarrow 15(T - 12) = 16(28 - T)$
$\Rightarrow T = 20.26°C \approx 20.3°C.$

40. (c) : Heat lost $= mL + ms_w(100 - 90)$
$= 540m + 10m = 550m$
Heat gained $= (100)(1)(90 - 24)$
$\Rightarrow 100 \times 66 = 550m$ or $m = 12$ g

41. (b) : Heat lost by water in cooling from 10°C to 5°C
= (5g) (1 cal/g/°C)(10 – 5)°C = 25 cal

Heat required to melt all the ice $= (g)\left(\frac{80 \text{ cal}}{g}\right) = 80$ cal

As water can't provide sufficient heat to melt all the ice, the final mixturing of ice and water is at 0°C.

42. (b) : $(200)(s_s)(60 - 20) = (200)(s_w)(80 - 60)$

$$\Rightarrow s_s = (s_w)\frac{(20)}{40} = \frac{s_w}{2}$$