

11.6 SPECIFIC HEAT CAPACITY

Take some water in a vessel and start heating it on a burner. Soon you will notice that bubbles begin to move upward. As the temperature is raised the motion of water particles increases till it becomes turbulent as water starts boiling. What are the factors on which the quantity of heat required to raise the temperature of a substance depend? In order to answer this question in the first step, heat a given quantity of water to raise its temperature by, say 20 °C and note the time taken. Again take the same amount of water and raise its temperature by 40 °C using the same source of heat. Note the time taken by using a stopwatch. You will find it takes about twice the time and therefore, double the quantity of heat required raising twice the temperature of same amount of water.

In the second step, now suppose you take double the amount of water and heat it, using the same heating arrangement, to raise the temperature by 20 °C, you will find the time taken is again twice that required in the first step.

In the third step, in place of water, now heat the same quantity of some oil, say mustard oil, and raise the temperature again by 20 °C. Now note the time by the same stopwatch. You will find the time taken will be shorter and therefore, the quantity of heat required would be less than that required by the same amount of water for the same rise in temperature.

The above observations show that the quantity of heat required to warm a given substance depends on its mass, m , the change in temperature, ΔT and the nature of substance. The change in temperature of a substance, when a given quantity of heat is absorbed or rejected by it, is characterised by a quantity called the **heat capacity** of that substance. We define heat capacity, S of a substance as

$$S = \frac{\Delta Q}{\Delta T} \quad (11.10)$$

where ΔQ is the amount of heat supplied to the substance to change its temperature from T to $T + \Delta T$.

You have observed that if equal amount of heat is added to equal masses of different substances, the resulting temperature changes will not be the same. It implies that every substance has a unique value for the amount of

heat absorbed or given off to change the temperature of unit mass of it by one unit. This quantity is referred to as the **specific heat capacity** of the substance.

If ΔQ stands for the amount of heat absorbed or given off by a substance of mass m when it undergoes a temperature change ΔT , then the specific heat capacity, of that substance is given by

$$s = \frac{S}{m} = \frac{1}{m} \frac{\Delta Q}{\Delta T} \quad (11.11)$$

The **specific heat capacity** is the property of the substance which determines the change in the temperature of the substance (undergoing no phase change) when a given quantity of heat is absorbed (or given off) by it. It is defined as the amount of heat per unit mass absorbed or given off by the substance to change its temperature by one unit. It depends on the nature of the substance and its temperature. The SI unit of specific heat capacity is $\text{J kg}^{-1} \text{K}^{-1}$.

If the amount of substance is specified in terms of moles μ , instead of mass m in kg, we can define heat capacity per mole of the substance by

$$C = \frac{S}{\mu} = \frac{1}{\mu} \frac{\Delta Q}{\Delta T} \quad (11.12)$$

where C is known as **molar specific heat capacity** of the substance. Like S , C also depends on the nature of the substance and its temperature. The SI unit of molar specific heat capacity is $\text{J mol}^{-1} \text{K}^{-1}$.

However, in connection with specific heat capacity of gases, additional conditions may be needed to define C . In this case, heat transfer can be achieved by keeping either pressure or volume constant. If the gas is held under constant pressure during the heat transfer, then it is called the **molar specific heat capacity at constant pressure** and is denoted by C_p . On the other hand, if the volume of the gas is maintained during the heat transfer, then the corresponding molar specific heat capacity is called **molar specific heat capacity at constant volume** and is denoted by C_v . For details see Chapter 12. Table 11.3 lists measured specific heat capacity of some substances at atmospheric pressure and ordinary temperature while Table 11.4 lists molar specific heat capacities of some gases. From Table 11.3 you can note that water

Table 11.3 Specific heat capacity of some substances at room temperature and atmospheric pressure

Substance	Specific heat capacity (J kg ⁻¹ K ⁻¹)	Substance	Specific heat capacity (J kg ⁻¹ K ⁻¹)
Aluminium	900.0	Ice	2060
Carbon	506.5	Glass	840
Copper	386.4	Iron	450
Lead	127.7	Kerosene	2118
Silver	236.1	Edible oil	1965
Tungsten	134.4	Mercury	140
Water	4186.0		

has the highest specific heat capacity compared to other substances. For this reason water is also used as a coolant in automobile radiators, as well as, a heater in hot water bags. Owing to its high specific heat capacity, water warms up more slowly than land during summer, and consequently wind from the sea has a cooling effect. Now, you can tell why in desert areas, the earth surface warms up quickly during the day and cools quickly at night.

Table 11.4 Molar specific heat capacities of some gases

Gas	C_p (J mol ⁻¹ K ⁻¹)	C_v (J mol ⁻¹ K ⁻¹)
He	20.8	12.5
H ₂	28.8	20.4
N ₂	29.1	20.8
O ₂	29.4	21.1
CO ₂	37.0	28.5

11.7 CALORIMETRY

A system is said to be isolated if no exchange or transfer of heat occurs between the system and its surroundings. When different parts of an isolated system are at different temperature, a quantity of heat transfers from the part at higher temperature to the part at lower temperature. The heat lost by the part at higher temperature is equal to the heat gained by the part at lower temperature.

Calorimetry means measurement of heat. When a body at higher temperature is brought in contact with another body at lower temperature, the heat lost by the hot body is

equal to the heat gained by the colder body, provided no heat is allowed to escape to the surroundings. A device in which heat measurement can be done is called a **calorimeter**. It consists of a metallic vessel and stirrer of the same material, like copper or aluminium. The vessel is kept inside a wooden jacket, which contains heat insulating material, like glass wool etc. The outer jacket acts as a heat shield and reduces the heat loss from the inner vessel. There is an opening in the outer jacket through which a mercury thermometer can be inserted into the calorimeter (Fig. 11.20). The following example provides a method by which the specific heat capacity of a given solid can be determined by using the principle, heat gained is equal to the heat lost.

► **Example 11.3** A sphere of 0.047 kg aluminium is placed for sufficient time in a vessel containing boiling water, so that the sphere is at 100 °C. It is then immediately transferred to 0.14 kg copper calorimeter containing 0.25 kg water at 20 °C. The temperature of water rises and attains a steady state at 23 °C. Calculate the specific heat capacity of aluminium.

Answer In solving this example, we shall use the fact that at a steady state, heat given by an aluminium sphere will be equal to the heat absorbed by the water and calorimeter.

Mass of aluminium sphere (m_1) = 0.047 kg

Initial temperature of aluminium sphere = 100 °C

Final temperature = 23 °C

Change in temperature (ΔT) = (100 °C - 23 °C) = 77 °C

Let specific heat capacity of aluminium be s_{Al} .