THERMAL PROPERTIES OF MATTER

CALORIMETRY

CALORIMETRY

Calorimetry, a branch of science concerned with the measurement of heat, involves the use of a calorimeter, a vessel commonly employed for such measurements.

Principle of Calorimetry: When two bodies at different temperatures exchange heat until they reach a common temperature, and assuming no heat is transferred to or from external sources, and no chemical reactions occur during the process, the principle of calorimetry asserts that the heat gained is equal to the heat lost. This statement is grounded in the law of conservation of energy.

Some Important Definitions:

Units of Heat: In the conventional system, the unit of heat is the calorie (cal). Historically, it was initially defined as the amount of heat required to raise the temperature of 1 gram of water by 1°C. In terms of the SI unit of energy, the joule (J), 1 cal is equivalent to 4.186 J.

Another unit of heat is the kilocalorie (kcal), where 1 kcal equals 1000 cal or 4186 J.

Example.

In an investigation concerning the specific heat of a metal, a block of metal weighing 0.20 kg and initially at a temperature of 150°C is immersed in a copper calorimeter. The calorimeter, with a water equivalent of 0.025 kg, holds 150 cc of water at 27°C. Following the process, the final temperature is recorded as 40°C. The task at hand is to compute the specific heat of the metal.

Solution.

Given mass of metal M = 0.20 kg = 200 g.

Total mass of calorimeter = (m + w) = (150 cc x 1 g/cc + 0.025 x 1000) g.

(Density of water = 1 g/cc)

Fall in temperature of metal = 150 - 40 = 110°C.

Rise in temperature of water = 40-27 = 13°C.

Heat lost by metal = MC (110) = 22000 C

Heat gained by calorimeter = $(m \times w) \times 1 \times (13) = 2275\ cal$ (specific heat capacity of water = 1 cal g-1°C-1)

As heat lost = heat gained.

∴ 22000 C = 2275

Solving we get C = 0.1 cal/gm°C

Example.

A coffee maker designed for consumers, with a power rating of 850 watts, is capable of brewing 10 cups, equivalent to 1.75 liters, of coffee. The initial temperature of the tap water used is 20°C, and the desired final temperature of the coffee is 80°C. The entire coffee-making process takes 10 minutes. The task is to determine the percentage of electrical energy consumed by the coffee maker that is effectively utilized in heating the coffee.

Solution.

The energy required to heat the water, denoted as(Q_{out}), is calculated using the formula ($Q_{out} = mc\Delta T$), where m is the mass of water (1.75 kg), c is the specific heat capacity of water (4200 J/kg K), and ΔT is the temperature change (80 - 20°C).

$$Q_{out} = (1.75\ kg)(4200\ J/kg\ K)(80\ -\ 20°C)\ =\ 441{,}000\ J$$

The energy consumed by the coffee maker, denoted as W_{in}, is calculated using the formula $W_{in} = Pt$, where P is the power of the device (850 W), and t is the time duration (10 minutes converted to seconds).

$$W_{in} = (850\ W)(10\ min)\ (60s/min)\ =\ 510{,}000\ J$$

The efficiency of the device (η) is expressed as the ratio of the energy output to the energy input, i.e., $\eta\ = \frac{Q_{out}}{W_{in}}$ which yields 86.5%.