6.5 HEAT AND TEMPERATURE

Heat is defined as energy which flows from one place to another owing to a temperature difference between them. Temperature is a measure of heat on some chosen scale.

6.5.1 Temperature Scales

Temperature is measured by a thermometer. The thermometer generally has two fixed points called the fundamental interval. This is divided into 100 equal degrees, the ice point being 0°C and the steam point 100°C. This is the celsius scale and the temperature on it is measured in degrees Celsius.

Another method of subdividing the interval is the Farenheit scale. In this the ice point is 32° and the steam point 212°, so there are 180 degrees in this scale. The relation between the two is given by

$$°\text{Celsius} = \frac{°F - 32°}{1.8} = K - 273 \qquad (6.10)$$

(k = kelvin, 0°C = 273°k)

The simplest method of measuring temperature is using an accurate thermometer of the standard type, calibrated to measure 1/100th of a degree centigrade (Fig.6.4a). Nowadays, temperature probes are available to measure temperature at depths in the soil and water as well as for measurement in industrial stacks.

A variant of this is the Six's maximum and minimum thermometer (Fig. 6.4b) to record the maximum and minimum temperature during the day and night respectively. It consists of a fairly large cylindrical bulb A containing creosote oil. This is connected by a U shaped stem to a second bulb B nearly filled with the same liquid. The bend of the U contains a thread of mercury. Two scales are provided, one against each limb of the tube so that the temperature may be read against either of the mercury levels. Resting on each of the mercury surfaces are small steels indexes provided with light springs to hold them in position in the stem. Expansion or contraction of the liquid in A causes a movement of the mercury thread.

When the temperature rises, the oil in the large bulb A expands and pushes down the mercury column with which it is in contact, pushing forward the index and driving the oil in the other bulb B. The other end of the mercury column thus rises. When the temperature falls, the oil in the larger bulb contracts and the mercury level on the left side rises and pushes the index, leaving it at the highest position reached. The lower end of the index on the left gives the minimum temperature while, the lower end of the index on the right gives the maximum temperature.

After readings have been taken a small magnet is used to bring the indexes back into contact with the mercury.

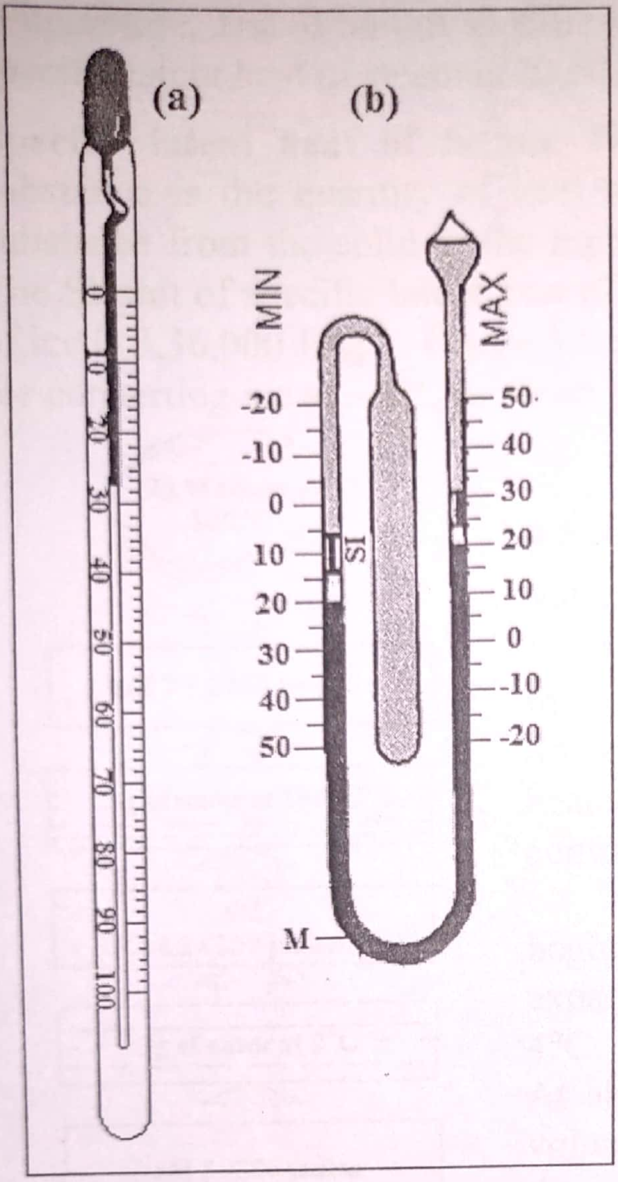

Figure 6.4 (a) standard thermometer
(b) Six's thermometer
(SI: steel index, M: mercury).

6.5.2 Thermal Units of Heat

The two most important units of heat that come into general use is the calorie (cal), and kilocalorie (kcal). The calorie is defined as the quantity of heat required to raise the temperature of 1g of water through 1°C. The kilocalorie is defined as the quantity of heat required to ráise the temperature of 1kg of water through 1°C. The relation between the thermal units of heat and mechanical units of energy is given as follows:

1 calorie = 4.2 Joules

Specific heat: The specific heat of a substance is the ratio of the quantity of heat required to raise a given mass of a substance through a range of temperature to the quantity of heat required to raise an equal mass of water through the same range of temperature.

Heat capacity: The heat capacity of a substance is defined as the heat required to raise its temperature by 1°C. The SI unit of heat capacity is joule per degree.

Specific heat capacity: The specific heat capacity of a substance is defined as the heat required to raise a unit mass of it through 1°C. The SI unit of specific heat capacity is J (joule per kilogram degree C). The specific heat capacity of water is 4200 J $kg^{-1}°C^{-1}$ (1 cal $g^{-1}°C^{-1}$). The word 'specific' is used in physics when we refer to unit quantity of a physical property. The specific heat of ice is 2100 J.

Specific latent heat of vapourization: The specific latent heat of vapourization of a substance is the quantity of heat required to change a unit mass of the substance from the liquid to the vapour state without change of temperature. The SI unit of specific latent heat of vapourization is J kg^{-1}. The specific latent heat of steam is 22,60,000 J kg^{-1}.

Specific latent heat of fusion: The specific latent heat of fusion of a substance is the quantity of heat required to convert a unit mass of the substance from the solid to the liquid state without change of temperature. The SI unit of specific latent heat of fusion is J kg^{-1}. The specific latent heat of ice is 3,36,000 J kg^{-1} . Figure 3.5 shows the heat required at various stages for converting ice at – 5°C to steam at 100°C.

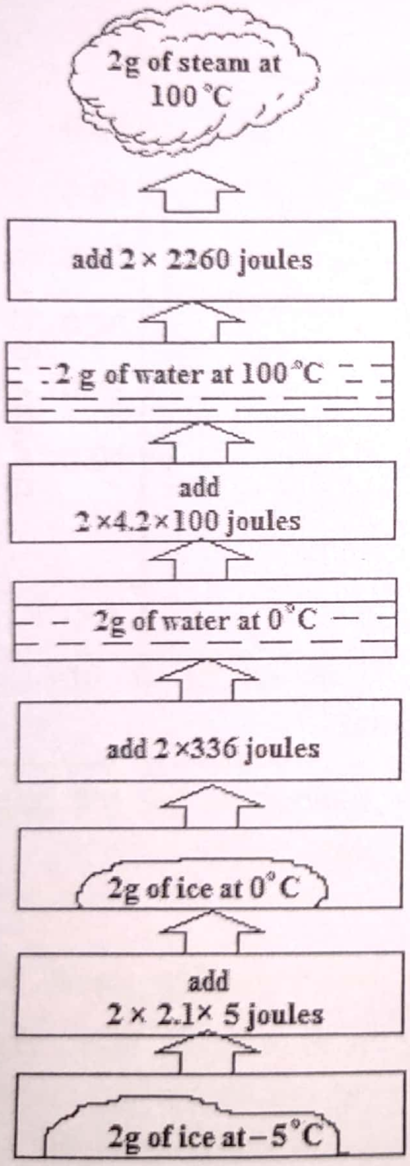

Figure 6.5 Heat required at various stages when 2g of ice at -5°C are completely converted to steam at 100 °C.

6.5.3 Heat and Density

Substances expand when heated. When a fixed mass of substance expands, the increase in volume brings about a decrease in density. Some substances do not always expand when heated. Over certain temperature ranges they contract. Water is an outstanding example.

If we take some water at 0°C and begin to heat it, the water contracts instead of expanding over the temperature range 0 to 4°C. Its behaviour is said to be anomalous. At about 4°C the water reaches its smallest volume, and consequently its maximum density (Fig. 3.6). If we continue to raise the temperature, the water now expands.

The peculiar expansion of water has an important bearing on the preservation of aquatic life during very cold weather. As the temperature of a pond or lake falls, the water contracts, becomes denser and sinks. A circulation is thus set up until all the water reaches its maximum density at 4°C. If further cooling occurs any water below 4°C will stay at the top owing to its lighter density. In due course ice forms on the top of the water, and after this the lower layers of water at 4°C can lose heat only by conduction. In deeper waters there will always be water beneath the ice in which organisms can live.

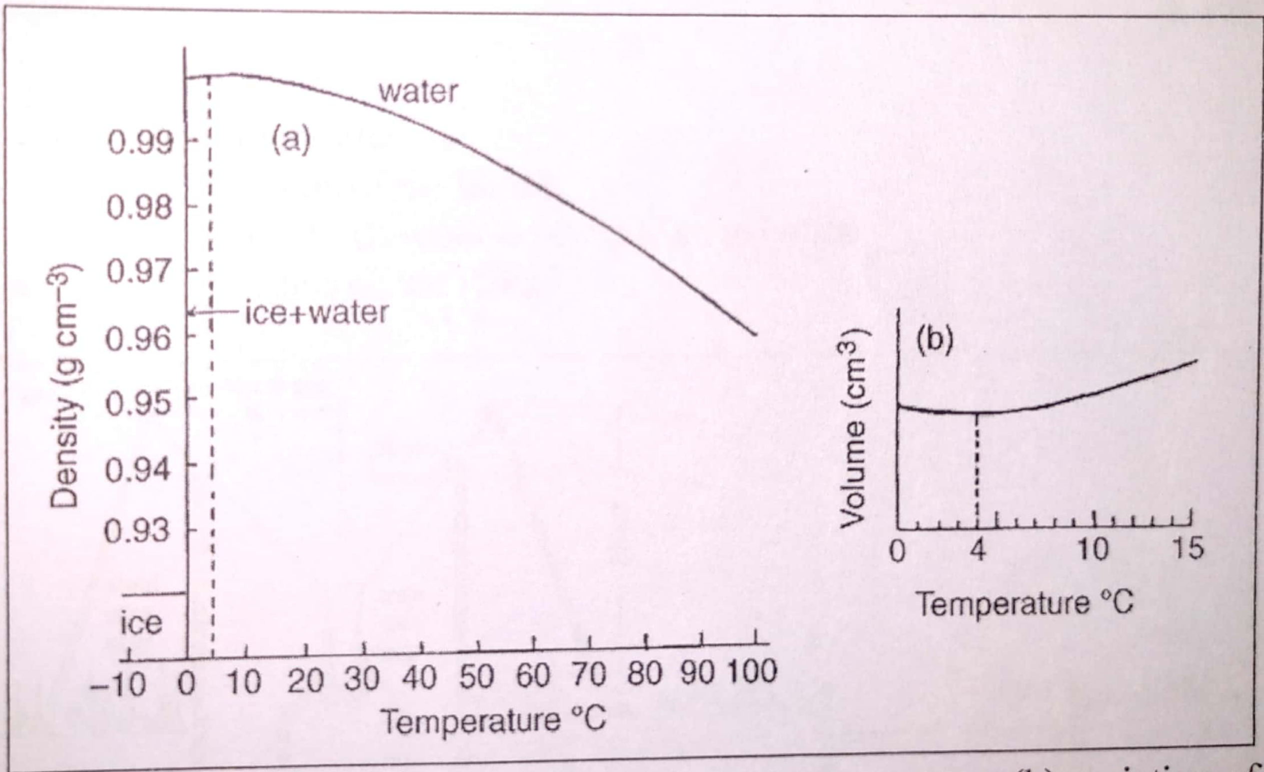

Figure 6.6 (a) Variation of water density with temperature (b) variation of water volume with temperature.