ABSOLUTE SCALE OF TEMPERATURE

Absolute scale of temerature → An absolute scale of temperature is a scale which is independent of characteristics of any particular substance. It coincides with the perfect gas scale.

In thermometry, all scales depend upon the properties of a particular substance, e.g. expansion of mercury, the change in resistance of platinum, etc with rise of temperature.

The efficiency of the reversible Carnot engine is independent of the working substance and depends only on the two temperatures of the source and sink $\left(\eta = 1 - \frac{T_2}{T_1}\right)$. This fact led Kelvin to suggest a new scale of temp. called Thermodynamics scale or Kelvin scale or Kelvin scale of temp. in the following way:-

Since the efficiency of all reversible engines working between any two temperatures θ_1 and θ_2 is a function of these two temp. alone, we may write

$$\eta = f(\theta_1, \theta_2) = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}.$$

Where Q_1 = amount of heat absorbed at the higher temp. θ_1

Q_2 = amount of heat rejected at the lower temp. θ_2.

θ_1 & θ_2 being measured on any arbitrary scale.

or, $$1 - \frac{Q_2}{Q_1} = f(\theta_1, \theta_2)$$

or, $$\frac{Q_2}{Q_1} = 1 - f(\theta_1, \theta_2)$$

or, $$\frac{Q_1}{Q_2} = \frac{1}{1 - f(\theta_1, \theta_2)} = F(\theta_1, \theta_2) \quad \text{—} (1)$$

Where 'F' denotes some other function of θ_1 and θ_2.
Similarly, for the reversible engine working between the temp. θ_2 and θ_3 $(\theta_2 > \theta_3)$:

$$\frac{Q_2}{Q_3} = F(\theta_2, \theta_3) \quad \text{—— (2)}$$

and working for temp. interval θ_1 and θ_3 $(\theta_1 > \theta_3)$

$$\frac{Q_2}{Q_3} = F(\theta_2, \theta_3) \quad \text{—— (3)}$$

(1) $\times$ (2) gives

$$\frac{Q_1}{Q_2} \times \frac{Q_2}{Q_3} = \frac{Q_1}{Q_3} = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3)$$

or, $$F(\theta_1, \theta_3) = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3) \quad \text{—— (4)}$$

This relation (4) is to be satisfied, $F(\theta_1, \theta_2)$ must be of the form $\frac{\psi(\theta_1)}{\psi(\theta_2)}$ where ψ is another function of temperature.

Therefore, for any reversible engine

$$\frac{Q_1}{Q_2} = \frac{\psi(\theta_1)}{\psi(\theta_2)} \quad \text{— — — (5)}$$

$\because$ $\theta_1 > \theta_2$ and $Q_1 > Q_2$, $\psi(\theta_1) > \psi(\theta_2)$ which means that $\psi(\theta)$ is a linear function of θ and may be used to measure temperature.

Expressing, therefore, $\psi(\theta)$ by T, which would be some multiple of θ:

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \quad \text{—— (6)}$$

Relation expressed in (6) can be used to define a new scale of temp. which doesnot depend on the properties of any particular substance. The ratio of any two temp. on this scale is equal to the ratio of the heat taken in and heat rejected by an engine working reversibly between the two temp. Hence it is called the absolute or the thermodynamic scale.

Eqn (6) may be written as:

$$\frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1} \quad \text{--- (7)}$$

Since $(Q_1 - Q_2)$ represents the work (W) done by the reversible engine between the two temperatures T_1 and T_2, the new scale is also called the 'work scale'.

The efficiency of the reversible engine on the absolute scale is defined as:

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \quad \text{--- (8)}$$

For 'η' to be unity, T_2 should be zero. But the efficiency can be unity only when all the heat taken by the engine is converted into work i.e., when $Q_1 = W$ or $Q_2 = 0$ or $T_2 = 0$. This represents the zero of the absolute scale. A temp. less than $T_2 = 0$ is not possible since then T_2 will be negative which means that the efficiency 'η' will be greater than one, which is impossible.

→ Relation between Absolute Scale & Perfect gas scale:

For, a reversible engine using a perfect gas as the working substance, the efficiency 'η' is given as:

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \quad \text{--- (9)}$$

where T_1 and T_2 are the temp. of the source and sink, measured on the perfect gas scale.
comparing (9) with (8), we get

$$\frac{T_1}{T_2} = \frac{\tau_1}{\tau_2} \quad \text{--- (10)}$$

The relation (10) indicates that ratio of any two temperatures on the perfect gas scale ($\frac{T_1}{T_2}$) and the thermodynamics scale (τ_1/τ_2) are equal. Since, if $\tau_2 = 0$, $T_2 = 0$, the zero of the thermodynamic scale coincides with the zero of the perfect gas scale.
If T_1 is the temp. of boiling water and T_2 that of melting ice, measured on the perfect gas scale.

$$T_1 - T_2 = 100$$

on the Absolute scale we have for the same two fixed points, as shown above

$$\tau_1 - \tau_2 = 100$$

Using the perfect gas scale, the efficiency

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{100}{T_1}$$

and in terms of the absolute scale:

$$\eta = \frac{\tau_1 - \tau_2}{\tau_1}$$

Since the efficiency is the same

$$\frac{100}{T_1} = \frac{100}{\tau_1}$$

This means that the temp of the boiling points of water and the melting point of ice are identical on the two scales. In a similar manner, it can be shown that any temperature has the same value on the two scales which are therefore, identical. The Ice point on the Kelvin scale is 273.16 i.e. triple point of water.