Thermometry

Heat: We know that heat is a form of energy. This heat energy does not remain stored in any substance. Whenever two bodies at different temperature are kept in contact energy is transferred from the body at higher temperature to that at lower temperature. This transfer of energy takes place in the form of heat energy.

Thus energy can be conceived only when there is a transfer or transmission of energy. When body gains or losses energy in the form of heat energy generally results is a change in temperature.

Hence we can say that heat is the cause and the temperature is its effect.

Measurement of Temperature: The temperature can be measured by a thermometer. A Thermometer is based on the principle of variation of any physical property of matter with Temperature.

Liquid Thermometer: One end of a capillary tube is drawn in the form of a bulb and the bulb is filled with the liquid say mercury or alcohol etc and is known as thermometric substance.

Calibration of scale

Lower Fixed Point (L.F.P): The bulb of thermometer is immersed in melting ice, the level up to which Hg rises in the capillary tube is marked and is known as L.F.P. It is O^0C or 32^0F

Upper Fixed Point (U.F.P): The bulb of the thermometer is immersed in boiling water in a hypsometer where water is boiled at normal pressure. The level up to which Hg rises in the capillary tube is marked and is known as upper fixed point. It is 100^0C or 212^0F or 80^0R.

The difference between the U.F.P and L.F.P is known as fundamental interval.

In Celsius (Centigrade) scale: Fundamental interval =100

In Fahrenheit scale : Fundamental interval =212 -32 =180

Celsius Scale: The gap between the two fixed points in the capillary tube is divided into 100 equal points and each part is called one degree centigrade or Celsius.

Fahrenheit Scale: The gap between the two fixed points in the capillary tube is divided into 180 equal parts and each part is called one degree Fahrenheit.

100 divisions in Celsius scale = 180 divisions in Fahrenheit scale

C-0 divisions in Celsius scale = 180(C-0)/100 divisions in Fahrenheit scale.

But in Fahrenheit scale the same gap contains F-32 divisions

Where C and F are the readings in Celsius scale and Fahrenheit scale respectively.

$$\frac{180(C-0)}{100} = F - 32$$

$$\frac{C-0}{100} = \frac{F-32}{180} = \frac{R-0}{80}$$

$$\frac{\text{Reading on the scale - L.F.P}}{\text{F.I}} = \text{Constant}$$

Draw backs of liquid thermometer:

(1) The maximum and minimum temperature that can be measured by a liquid thermometer is limited by the boiling point and the freezing point of the liquid, e.g. for Hg boiling point – 354^0C and freezing point = -39^0C

(2) The volume expansion of liquid is not same throughout the entire temperature range but mark on the scale are uniform throughout hence the readings of the liquid thermometer are not accurate.

(3) The coefficient of volume expansion of different liquids are different hence two thermometers containing two different liquids will agree only at 0^0C & 100^0C and probably at no other temperature.

(4) The volume coefficient of expansion of liquid being small liquid thermometer are insensitive towards small temperature change.

(5) The expansion of the containing vessel requires a correction.

Advantage of using gas as thermometric substance

(1) The volume expansion of gas is very large about twenty times greater than that of liquid. Hence gas thermometers are much more sensitive than liquid thermometers.

(2) The volume coefficient of expansion and pressure coefficient of expansion is same for real gases hence the reading of gas thermometer does not depend on the nature of the gas used.

(3) The thermal capacity of gas being low, gas thermometer absorbs very little heat from the bath and quickly attains the temperature of the bath.

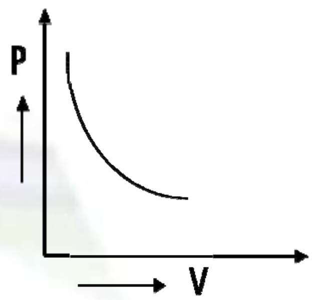
(4) The volume expansion of gas being very large compared to solid no correction is generally required for the expansion of the containing vessel.

(5) Specific gravity of gas being low gas can be easily found in pure form.

Principle of gas thermometry:

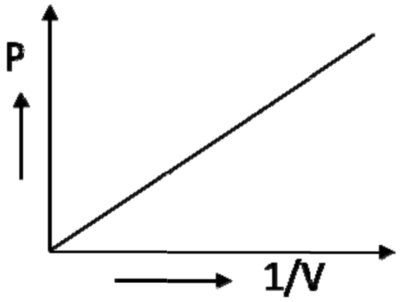
(1) Boyle's law: For a definite mass of gas at constant temperature the volume of the gas is inversely proportional to the pressure of the gas.

$$P \propto \frac{1}{V} \quad \text{when T is constant}$$
$$\text{or PV} = \text{constant} \quad \text{when T is constant}$$
$$\text{i.e. } P_1V_1 = P_2V_2 \rightarrow (1)$$



Thus we draw a graph with pressure along Y axis and volume along X axis then we get a rectangular hyperbola.

If we draw a graph putting pressure along Y axis and 1/V along X axis we get a straight line passing through the origin.



Charles Law: It gives the variation between

(1) Volume with temperature when pressure is constant

(2) Pressure with temperature when volume is constant

(1) Variation of volume with temperature: At constant pressure the volume of a gas increases with the increase in temperature and is given by

$$V_t = V_0(1+\gamma_v t) \rightarrow (1)$$

Where V_0 & V_t = Volume of the gas at 0^0C & t^0C respectively

γ_v = The temperature coefficient of volume expansion of the gas and is same for all real gases.

$$\gamma_v = \frac{1}{273.15} \approx \frac{1}{273}$$

Let t = -273^0C

from equation(1): $V_{-273} = V_0\left(1+\frac{-273}{273}\right) = 0$

Thus we see that at -273^{0}C the volume of a gas vanishes and below -273^{0}C the volume of a gas is negative, which is impossible. Hence we conclude that -273^{0}C is lowest possible temperature in this universe and hence it is known as absolute zero.

$$t^0C = (273+t)K$$

$$0^0C = 273K$$

$$\therefore V_t = V_0\left(1+\frac{t}{273}\right)$$

$$V_t = V_0\left(\frac{273+t}{273}\right) \qquad \{\ T = 273+t,\ T_0 = 273\ \}$$

$$V_t = V_0\left(\frac{T}{T_0}\right)$$

$$\frac{V_t}{T} = \frac{V_0}{T_0}$$

$V \propto T$ when P is constant

Volume of a gas is directly proportional to the absolute temperature when pressure is constant.

(ii) **Variation of pressure of a gas with temperature**: When the volume of a gas is kept constant pressure of a gas increases with the increase in temperature and is given by

$$P_t = P_0(1+\gamma_p t)$$

Where P_0 & P_t = Pressure of the gas at 0^0C and t^0C respectively.

γ_p = The temperature coefficient of pressue expansion of the gas and is same for all real gases.

$$\gamma_p = \frac{1}{273.15} \approx \frac{1}{273}$$

$$P_t = P_0\left(1+\frac{1}{273}t\right)$$

$$P_t = P_0\left(\frac{273+t}{273}\right)$$

$$P_t = P_0\left(\frac{T}{T_0}\right)$$

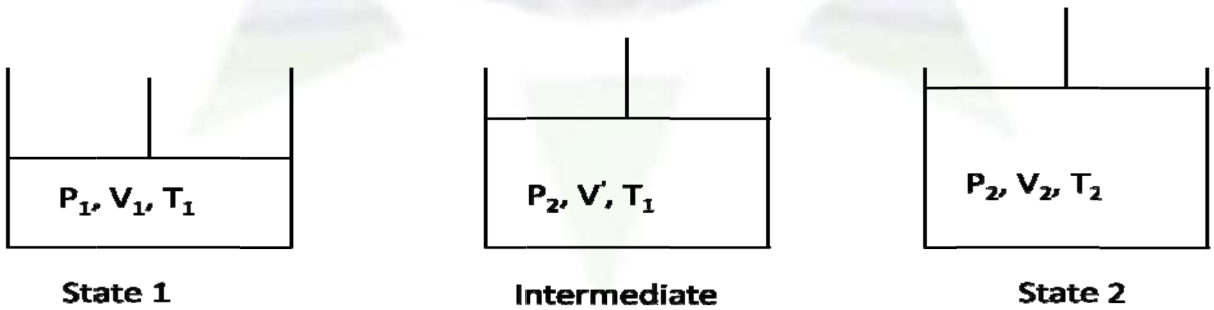
$$\frac{P_t}{T} = \frac{P_0}{T_0}$$

$P \propto T$ when V is constant

Thus pressure of a gas is directly proportional to the absolute temperature when volume of the gas is constant.

Boyles and Charles law combined:

Let us consider a gas at pressure P_1 , Volume V_1 and temperature T_1 and this gas is to be taken to a different state P_2,V_2 and T_2.



In passing from state 1 to state 2 let us consider an intermediate state which is obtained as follows, temperature is kept constant at T_1, pressure is changed from P_1 to P_2 and let the volume change from V_1 to V'

Using Boyle's law: $P_1V_1 = P_2V'$ (T_1 is constant)

$$V' = \frac{P_1V}{P_2} \rightarrow (1)$$

From the intermediate state we pass to the final state as follows:

Pressure is kept constant at P_2 the temperature is changed from T_1 to T_2 and let the volume changes from V' to V_2.

Applying Charles law:

$$\frac{V'}{T_1} = \frac{V_2}{T_2} \quad (\text{ P}_2 \text{ is constant })$$

$$V' = \frac{V_2 T_1}{T_2} \rightarrow (2)$$

From equation (1) and (2)

$$\frac{P_1 V_1}{P_2} = \frac{V_2 T_1}{T_2}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{PV}{T} = \text{Constant} = \text{nR}$$

$$\text{PV} = \text{nRT} \rightarrow (3)$$

Where R= Universal gas constant = 8.33 Joule per mole/^{0}K

n= no. of moles = mass of the gas/Molecular weight of the gas

Equation (3) is the equation of state or gas equation for a perfect gas.