(P-III) Heat and Thermodynamics

Unit 1 : Thermometry

Unit 2 : Real gases and their behaviour

Unit 3 : Transport phenomenon in Gases

Unit 4 : Thermodynamics and thermodynamical Relations.

Unit - 1

Thermometry

- Types of thermometers
- Centigrade and fahrenheit scale
- relation between celsius, kelvin, fahrenheit and Rankine scales.
- Platinum resistance thermometer
- Seebeck effect

Some Basic definitions

① Heat -

In thermodynamics, heat is energy in the form transfer to or from a thermodynamic system, by mechanism other than thermodynamic work or transfer of matter.

② Thermodynamics -

Thermodynamics is the branch of physics which deals with heat and temperature and their relation to energy, work & properties of matter.

Temperature is different from heat, although the two concepts are linked.

Temperature is a measure of a internal energy of the system, while heat is measure of how energy is transferred from one system (or body) to another.

Thermometry -

The branch of heat related to the measurement of temperature of a body is called as thermometry.

- The thermometer is an instrument used to measure the temperature of the body.

- The essential requirements of a thermometer are

1) construction
2) calibration
3) sensitiveness.

1) construction -

for the construction of a thermometer, the proper choice of substance, whose physical property varies uniformly with rise in temperature, is essential.

The mercury thermometer is based on the principle of expansion of mercury with rise in temperature.

In platinum resistance thermometer, the principle of change in resistance with change in temperature is used.

The gas thermometer is based on the principle of change in volume or pressure with change in temperature.

2) calibration -

When a thermometer is constructed, it must be properly calibrated.

The standard fixed points are selected for calibrating a thermometer. melting point of ice, boiling point of water, melting point of silver and melting point of gold are taken as fixed points.

The scales are built by dividing the interval between the melting point of ice and boiling point of water (under normal pressure) into 100 equal parts and each part represents 1°c. similarly, fahrenheit scale is build by dividing the scale in 180 equal parts.

3) Sensitiveness -

~~The~~ Once the instruement is constructed and calibrated, it should be sensitive.

The thermometer will be sensitive if

① it can detect small ~~te~~ changes in temperature

② it shows the temperature of a body in a short interval of time.

Types of thermometers -

There are different kinds of thermometers :

① Liquid thermometers

These thermometers are based on the principle of change in volume of a liquid with change in temperature. mercury and alcohol thermometers are based on this principle.

(2) Gas Thermometer-

These are based on the principle of change in pressure or volume with change in temperature.

Ex. constant volume hydrogen thermometer

(3) Resistance thermometers -

These are based on the principle al change in resistance with change in temperature.

Ex. Platinum resistance thermometer.

(4) magnetic thermometers -

These thermometers are based on the principle of change in the susceptibility of a substance with temperature.

These thermometers are useful for the measuring low temperatures near the absolute zero temperature.

(5) Radiation thermometers -

These are based on the quantity of heat radiations emitted by a body. Ex. furnances.

Celsius

Centig

Centigrade, fahrenheit and Rankine scales -

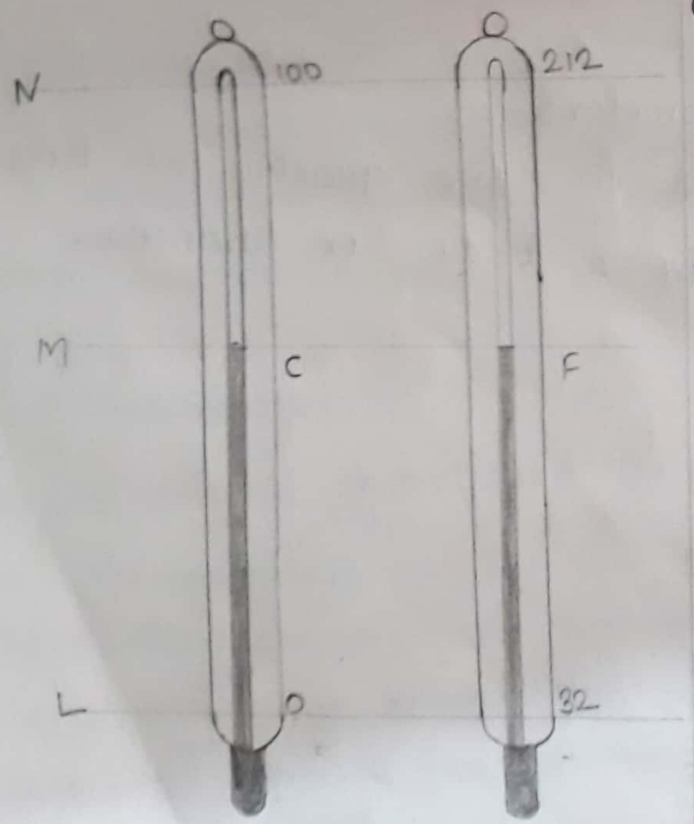
Centigrade (or celsius scale)

Celsius suggested the centigrade system of temperature. He marked zero at the lower fixed point and 100 at the upper fixed point. The interval between two fixed points is divided into 100 equal parts. each part represents 1°c or 1°celsius.

The scale is also known as celcius scale.

Fahrenheit scale

~~Fahrenheit suggested~~ The lower fixed point is marked as 32 and upper fixed point is marked as 212. The interval is divided into 180 equal parts. Each part or degree represents 1°F.



Centigrade Fahrenheit

Consider two identical thermometers marked in centigrade & fahrenheit scales. Place the two thermometers in a bath at certain fixed temperatures. Mercury in each thermometers stands to the same level M. as shown in fig.

$$\frac{ML}{MN} = \frac{C-0}{100-0}$$

$$= \frac{F-32}{212-32}$$

$$\boxed{\frac{C}{100} = \frac{F-32}{180}}$$

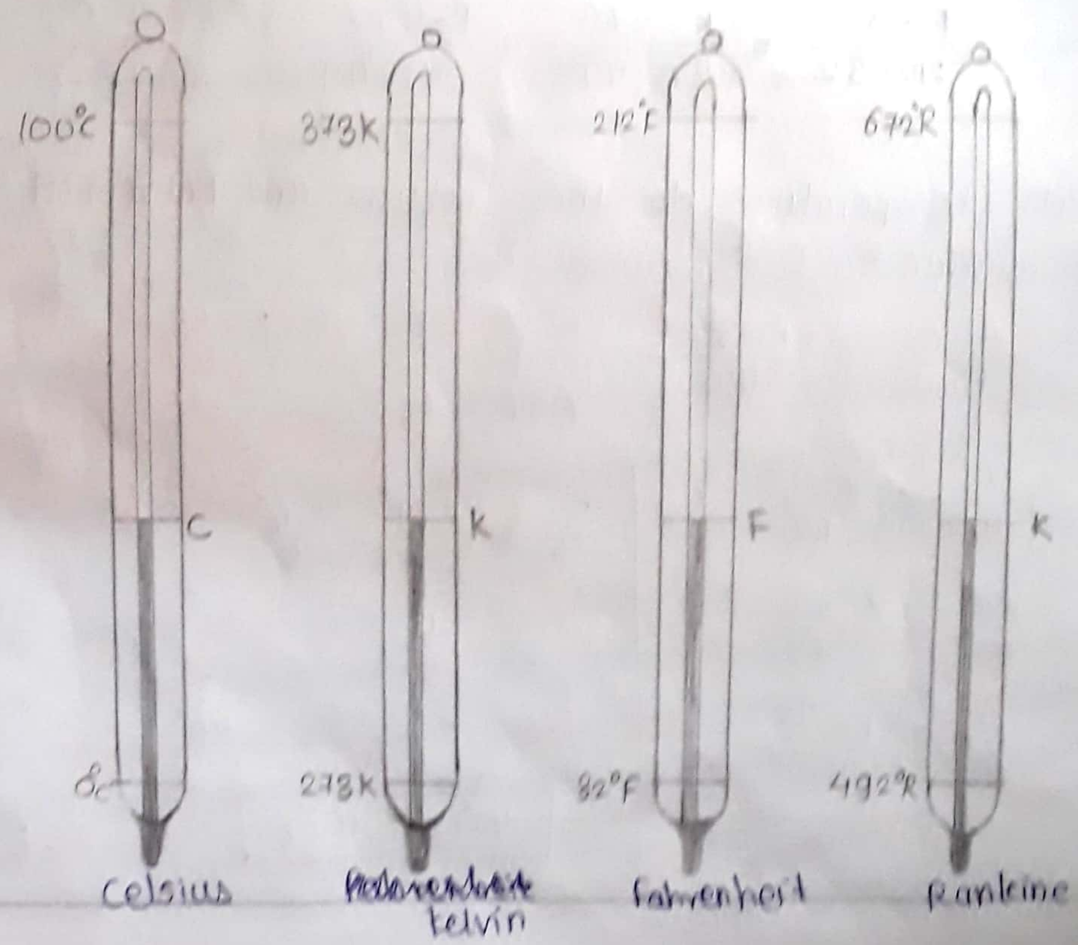
Relation between celsius, kelvin, fahrenheit and Rantine scales of temperature.

Celsius scale –

In this case, the lower fixed point is zero degree celsius and upper fixed point is 100°c. The interval between two fixed points is divided into 100 equal parts each part representing 1°c.

Kelvin scale –

The lower fixed point is 273 K and upper fixed point is 373 K. The interval between two fixed points is divided into 100 equal parts each part representing 1 K



Fahrenheit scale -

The lower fixed point is marked as 32°F and upper fixed point is marked as 212 °F. The interval is divided into 180 equal parts. each part or degree represents 1°F.

Rankine scale -

The lower fixed point is marked as 492 °R and upper fixed point is marked as 672. The interval is divided into 180 equal parts. each part or degree represents 1°R.

∴ The relation between °C, K, °F, °R is given by

$$\frac{C-0}{100} = \frac{F-32}{180} = \frac{K-273}{100} = \frac{R-492}{180}$$

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273} = \frac{R-492}{672-492}$$

At what temperature, do the celsius and Fahrenheit scales coincide ?

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

$C = F = x$

$$\frac{x}{100} = \frac{x-32}{180}$$

$$\frac{180}{100} = \frac{x-32}{x}$$

$$\frac{9}{5} = 1 - \frac{32}{x}$$

$$\frac{32}{x} = 1 - \frac{9}{5} = \frac{-4}{5}$$

$$\frac{32}{x} = \frac{-4}{5}$$

$$x = -\frac{32 \times 5}{4} = -40^{\circ}$$

∴ $-40^{\circ}C = 40^{\circ}F$

Liquid Thermometer -

Liquid thermometers are based on the principle of change of volume of liquid with change in temperature. The most commonly used liquids are mercury and alcohol.

The range of mercury thermometers is -39°c to 357°c.

alcohol thermometers are used only to measure temperature near ice point.

Mercury thermometer -

mercury is usually selected for use in liquid in glass thermometers for the following reasons.

① It ~~has~~ is a good conductor of heat and takes the temperature of the body quickly.

② It can be easily seen in a fine capillary tube and thermometer can be made sensitive.

③ It has an uniform coefficient of expansion over a wide range of temperatures.

④ It remains a liquid over a large range. Its freezing point is -39°c and the boiling point is 357°c.

Construction -

- It consists of a long capillary tube of glass with a uniform bore. A bulb is blown at one end. pure and dry mercury is filled in capillary tube from above by alternating heating and cooling the bulb. Then the tube is sealed off at upper end.
- The lower fixed point and upper fixed point are marked at the temp at which pure ice melts and temp. at which the pure water boils. The distance between the fixed points is divided into a no of equal sized parts called degrees.

Platinum resistance thermometers -

- It is based on the principle of change in resistance with change in temperature.
- A platinum resistance thermometer is a piece of platinum wire which determines the temperature by measuring its electrical resistance.
- It is referred as a temperature sensor.
- It was first designed by Sieman and later improved by Callendar and Griffiths.
- The temp. range is 200°c to 1200°c.

Construction -

A platinum resistance thermometer consists of a pure platinum wire wound in a double spiral to avoid inductive effects.

The wire is wound on a mica plate.

The two ends of the platinum wire are connected to thick copper leads (for lower temperatures) and connected to the binding terminals $B_1 B_2$.

for higher temperatures the leads are of platinum.

C_1 and C_2 are compensating leads exactly similar and of the same resistance as the leads used with platinum wire.

- The platinum wire and the compensating leads are enclosed in a glazed porcelin tube. The tube is sealed and binding terminals are provided at the top.
- The leads pass through mica discs which offers the best insulation and also prevents convection currents.
- The resistance of a wire at $t°C = R_t$ and the resistance of a wire at $0°c = R_o$.

~~These relations of a wire and thermal~~

These resistances are connected by the relations

$$R_t = R_o(1 + \alpha t + \beta t^2). \quad —①$$

Here α and β are constants.

The values of α and β depend on the nature of material used.

The fixed values of α and β; the resistance of platinum wire is determined at three fixed points.

① melting point of ice ② boiling point of water

③ boiling point of sulphur 444.6°c for high temperature measurement

④ boiling point of oxygen -182.5°c for low temperature measurement.

put these values in equation ①.

$$R_{100} = R_o[1 + \alpha(100) + \beta(100)^2] \quad —②$$

$$R_{444.6} = R_o[1 + \alpha(444.6) + \beta(444.6)^2] \quad —③$$

The values of α and β can be determined by solving the simaltaneous eqns ② & ③

and neglecting βt^2

$\therefore R_t = R_0[1+\alpha t] \Rightarrow R_t = R_0 + R_0\alpha t$

$R_{100} = R_0[1+\alpha 100]$

$R_t - R_0 = R_0 \alpha t$

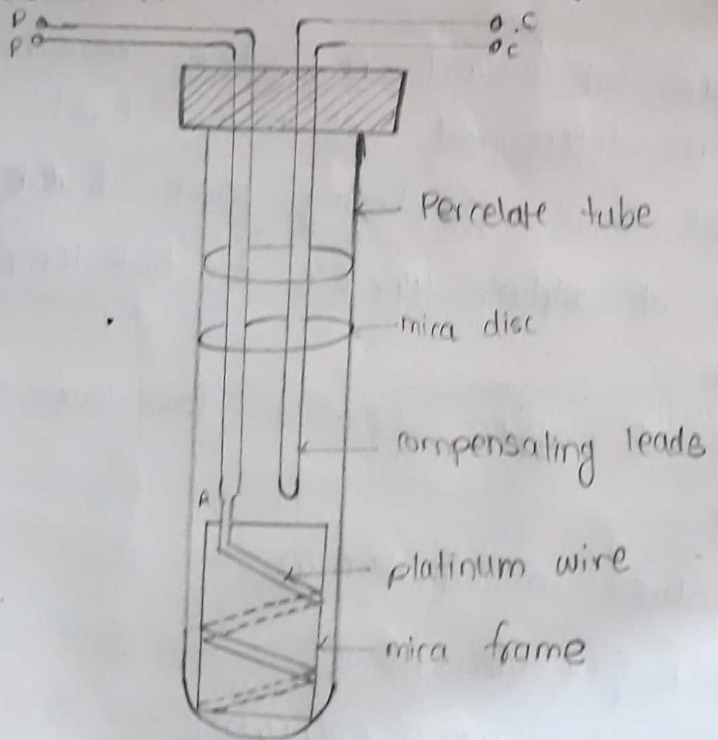
$R_{100} - R_0 = R_0 \alpha \cdot 100$

$$\frac{R_t - R_0}{R_{100} - R_0} = \frac{t}{100}$$

$$t = \left(\frac{R_t - R_0}{R_{100} - R_0}\right) \times 100$$

knowing the values of R_t, R_{100} and R_0, t can be calulated.

The resistance of platinum wire is found acurrately by callendar and Griffiths bridge.



Seebeck effect -

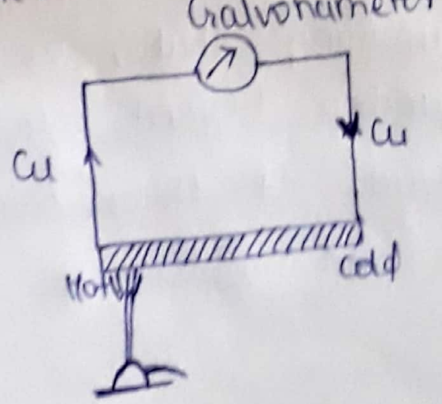
The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductor produces a voltage difference between the two substances.

When the heat is applied to one of the two conductors or semiconductors, heated electrons flow towards the cooler one.

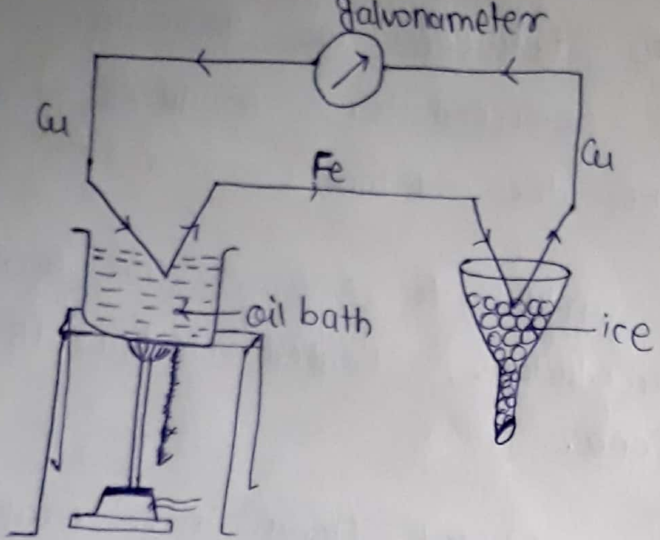
Seebeck found that a current flows in a circuit consisting of two dissimilar metals when one junction is heated while the other junction is kept cold.

This was a remarkable experiment because no cell was used in this circuit.

He connected a ~~plate~~ Bismuth plate between copper wires connected to a galvanometer. He found that if one of the junctions was heated while other was kept cold, then a current flowed through the galvanometer.



Also, he repeated his experiment by taking a thermocouple of Fe and Cu.



If both the junctions are at 0°c, there is no deflection in the galvanometer.

When one of the end (junction) is kept at 0°c ie temperature of melting point of ice and other junction is heated gradually, current flows in the circuit.

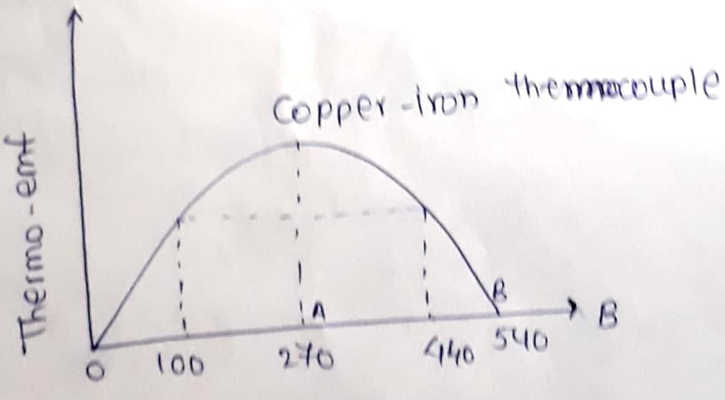
It was found that current flows from copper to iron at the hot junction and iron to copper at the cold junction. The current increases until the hot junction is at a temperature of 270°c. If the heating is continued beyond 270°c the current decreases and finally at 540°c the current is zero.

It was discovered by cumming that, on increasing temperature of the hot junction beyond 540°c, the direction of current is reversed. It flows from iron to copper through hot junction and copper to iron through the cold junction.

The current produced in this way without the use of a cell or battery is known as thermo-electric current & this branch of electricity is known as thermo-electricity. The effect is known as seebeck effect.

The temperature of the junction at which maximum current flows in a circuit is known as neutral temperature for that couple. The neutral temperature for a given thermocouple is fixed and remains constant whatever may be the temp. of cold junction. The Emf produced in this way is called as thermo emf.

If the graph is plotted between temperature of the hot junction and thermo emf, the cold junction being kept at 0°c the graph is parabolic.



point A represents neutral temperature.

point B represents temperature of inversion; beyond which the current is reversed.