DESIGN AND USE OF THERMOMETERS

Temperature & Thermometers

Temperature is a measure of the amount of thermal energy a body possesses in order to heat up a body, energy is required; this energy increases the body internal energy by increasing the kinetic energy of the particles.

Measuring temperature

Physical properties which vary with temperature may be used to measure it. This is done by choosing two experimental fixed points and measuring the values of the thermometric properties at these reference points. All other points may be obtained by linear interpellation.

Thermometric properties

- Volume
- Pressure
- Length
- Resistance

These physical properties vary continuously (over a range) with the degree of hotness.

Examples

1. Length: length of a column of liquid in a capillary tube (liquid in glass thermometer)
2. Resistance: resistance of a platinum wire (platinum resistance thermometer)
3. E.M.F E.M.F of thermocouple (thermocouple thermometer)
4. Pressure pressure of a fixed mass of gas at constant volume (constant volume gas thermometer)
5. the quantity (colour) of electromagnetic radiation emitted by a very hot body (optical pyrometer)

Thermometers

The following properties determine which thermometer is used to measure temperature in specific situations.

- Range
- Accuracy
- Sensitivity
- Response

Thermometer	Thermometric Property	Range (K)	Advantages	Disadvantages
Mercury in glass thermometer	Length of mercury in a capillary tube	234 – 630	- Portable - Cheap - Direct reading	- Not very accurate - Limited range
Constant volume gas thermometer	Pressure of a mass of gas at constant volume	0 – 750	- Wide range - Very accurate - Very sensitive	- Cumbersome - Big bulb - Slow to use
Platinum resistance thermometer	Electrical resistance of platinum	13.8 – 1400	- wide range - best for steady differences of temperature - most accurate in this range	- Slow response (not suitable for varying temperature)
Thermocouple	E.M.F. produced by two dissimilar wires	25 – 1750	- Wide range - Small probe can read temperature remotely	- -expensive sensors

Temperature Scales

In order to establish a temperature scale fixed points are fixed points are used. A fixed point is a single temperature at which particular event can be confidently expected to take place. There are three (3) fixed points.

1. The ice point: temperature at which pure ice can exist in equilibrium with water at standard atmosphere pressure.
2. The steam point: temperature at which pure water can exists in equilibrium with its vapour at standard atmospheric pressure.
3. The triple point: the triple point of water is that unique temperature at which pure ice, pure water vapour can exist in equilibrium together. [NB only one pressure at which triple point can occur]

Kelvin and Celsius scale

SI unit of temperature is Kelvin (K). An interval of one Kelvin is defined as $\frac{1}{273.16}$ of the temperature of triple point of water measured on thermodynamic scale of temperature.

The triple point of water is the fixed point of the scale which has a value of 173.14 K.

Ice point is 273.16 K and steam point 373.15 K.

We can convert from Kelvin (K) to degree Celsius (°C) by using: θ / (K) = T / (K) – 273.15

(NB. a temperature change of 1 K is equivalent to a temperature change of 1°C i.e. ΔK = Δ°C)

We can calibrate a mercury – in – glass thermometer by using the ice point and steam point. Then we divide the length / interval between these two points by 100 equal divisions. We can find any temperature on °C corresponding to any length (l_θ) by using the formula.

$$\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100$$

Where l_0 and l_{100} are lengths of 0 °C and 100 °C respectively.

The thermodynamic scale temperature

This scale is totally independent of any properties of any substance and is therefore the absolute scale is theoretical; it is identical to the scale based on pressure variation of ideal gas.

The fixed point on both of these scales is the triple point (273.16 K) the Kelvin temperature (T) on both scales can be calculated using

$$\mathbf{T = \frac{P_T}{P_{TR}} \times 273.16}$$

Where P_T is the pressure of an ideal gas at a given temperature

P_{TR} is pressure of same volume of gas at triple point of water

We can also use the following formula to calculate temperature in °C

$$\boldsymbol{\theta_g = \frac{P_{\theta - P_0}}{P_{100 - P_0}} \times 100}$$

Where P_θ corresponds to a temperature at θ_g

P_0 and P_{100} are pressure at 0°C respectively

$$\boldsymbol{\theta_r = \frac{R_{\theta - R_0}}{R_{100 - R_0}} \times 100}$$

Where R_θ corresponds to a temperature θ_r

R_0 and R_{100} are resistances at 0°C and 100°C respectively

Examples

1. A resistance thermometer has a 30.00 Ω at ice point and 41.58 Ω at steam point and 34.59 Ω when immersed in a boiling liquid.

   A constant volume – gas thermometer gives reading of 1.333×10^5 Pa, 1.821×10^5 Pa and 1.528×10^5 Pa for the same three temperatures.

   i) Calculate the temperature at which the liquid is boiling on

      a) scale of resistance thermometer

      b) scale of gas thermometer.

2. The resistance R_0 of a resistance thermometer at a Celsius temperature θ as measured by a constant volume gas thermometer is given by

   $$R_\theta = 50.00 + 0.1700\,\theta + 3.00 \times 10^{-4}\theta^2$$

   Calculate the temperature as measured on scale on resistance thermometer which corresponds to a temperature of 60 °C on the gas thermometer.

3. A resistance thermometer has a resistance of 21.42 **Ω** at the ice point, 29.10 **Ω** at the steam point and 28.11Ω at some unknown temperature θ. Calculate θ on the scale of this thermometer.

4. A particular constant – volume gas thermometer registers a pressure of $1.937 \text{ X } 10^4$ Pa at the triple point of water and $2.618 \text{ X } 10^4$ Pa at the boiling point of a liquid. What is the boiling point of the liquid according to this thermometer?