CHAPTER TEN

MEASUREMENT OF HEAT

Heat: This is the type of energy which flows from a region of a higher temperature to that of a lower temperature.

Temperature: This is a number which tells us how hot or cold a body is.

Distinction between heat and temperature:

(1) Temperature is a fundamental quantity, where as heat is a derived quantity.
(2) Temperature is a measure of the heat level, where as heat is a measure of the total internal energy of the body.
(3) Temperature is measured in Kelvin (K) where as heat is measured in joule, J.

Factors which determines the quantity of a heat possessed by a body:

These factors are:

(1) The mass of the body.
(2) The nature of the body.
(3)The body`s excess temperature over its` surrounding.

The effects of the addition of heat on substances:

- These effects are:
  (1) The expansion of the substances may occur.
  (2) It can cause an increase in the temperature of the substances, except when the substance is undergoing a change of state.
  (3) If the substance is an electrical conductor, then its electrical resistance can increase.
  (4) It can cause a substance to undergo a change of state.
  (5) It increases the rate of evaporation of a liquid, or the rate of sublimation of a solid.

Sources of heat:

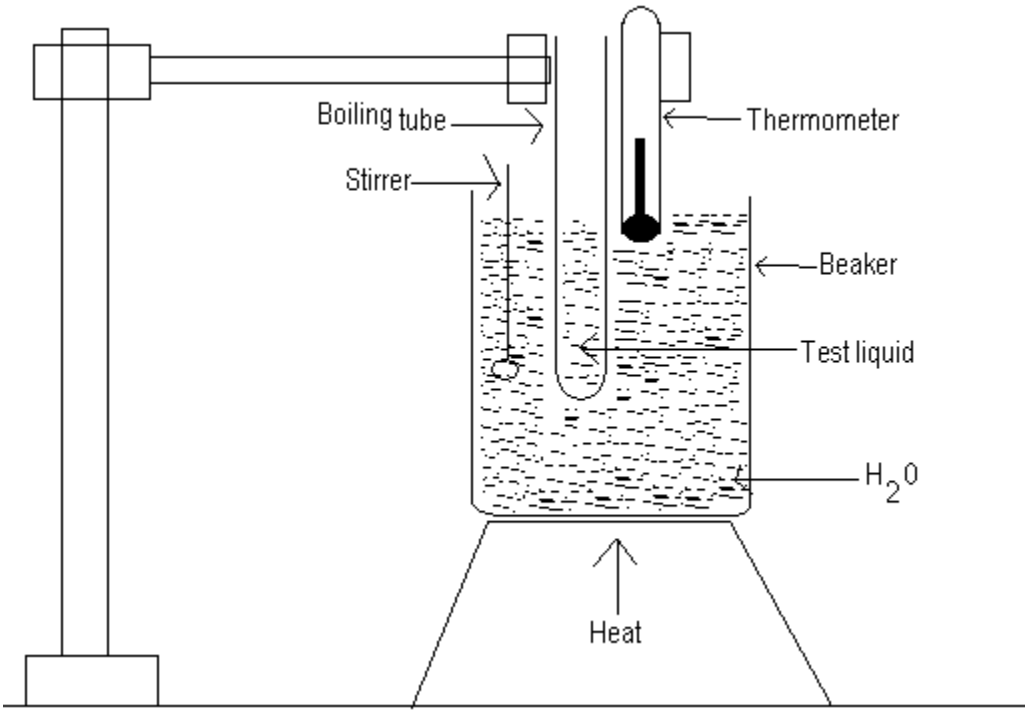
The main sources of heat include some natural and certain artificial sources. These include:

(a) Solar energy
(b) Fossil fuel (petroleum).
(c)Nuclear energy.
(d) Hydroelectric power.
(e) Geothermal energy.
(f) Friction.

Boiling and the boiling point:

- When a liquid is heated in a container, its temperature increases.
- As the temperature increases, the saturated vapour pressure of the liquid which forms on its upper surface also increases, and bubbles are formed throughout the liquid.
- At a particular point, the vapour pressure of the liquid becomes equal to the atmospheric pressure, and when this occurs, the bubbles will start to escape into the atmosphere.
- The liquid is then said to be boiling.
- The boiling point of a liquid is therefore defined as the temperature, at which its vapour pressure becomes equal to the atmospheric pressure.

The determination of the boiling point of a liquid, whose boiling point is less than 100^{0c} , [when a few drops are available]:



Procedure:

- In this experiment, a few drops of the liquid are placed in a boiling tube, and a thermometer is attached to it using a rubber band, so that the bulb of the thermometer is in line with the liquid in the boiling tube.
- The assembly is suspended by means of a clamp and a stand in a water bath.
- The water in the bath is continuously stirred as the water is slowly heated.
- The temperature at which the liquid begins to bubble is noted and this is taken as the boiling point of the liquid.

Precautions to be taken:

(1) The water is continuously stirred in order to obtain a uniform temperature within the water bath.
(2) The heating must be done slowly in order to obtain a thermal equilibrium between the boiling tube and the water.

(3) It must also be ensured that the thermometer is in line with the liquid in the boiling tube, so as to record the true temperature of the boiling liquid.

The assumptions of the Kinetic Theory:

These assumptions are:
(i) Gases are made up of small solid particles which are in constant random motion.
(ii) The particles move in straight lines and their motion is only affected by their collisions with other particles, or with the walls of the vessel in which they are contained.
(iii) All the collisions are perfectly elastic i.e. there is no loss of kinetic energy when two particles collide or a particle strikes the walls of a container.
(iv) The time for which the particles are actually in contact with each other, is very small and they may be neglected.
(v) The actual volume of the molecules is very small, compared with the volume of the container in which they are found.

Explanation of evaporation using the kinetic theory:

- As a result of the random collisions in a liquid, a molecule may acquire enough kinetic energy to break away from the attraction of their neighbours.
- They may also acquire a velocity which is greater than the average velocity of the liquid molecules, even though the temperature at that instant is well below the boiling point of the liquid.
-A molecule at the surface can leave the liquid, giving rise to the evaporation of the liquid.

Cooling by evaporation: According to the kinetic theory of matter, the temperature of a liquid is directly proportional to the average kinetic energy of its molecules. During evaporation, the more energetic molecules escape from the liquid surface, leaving behind the less energetic molecules. The average kinetic energy of the molecules remaining in the liquid falls, and as such the temperature of the liquid falls. This phenomenon is referred to as cooling by evaporation.

Comparing and contrasting boiling and evaporation:

(a) The differences between boiling and evaporation:

(1) Boiling takes place at a fixed temperature referred to as the boiling point, but evaporation takes place at any temperature.
(2) Boiling occurs throughout the whole body of the liquid (i.e. both surface and inside), but evaporation only occurs at the surface.
(3) During boiling, the temperature remains constant but during evaporation, the temperature may change.

(b) Similarities between boiling and evaporation:

(1) Both lead to the reduction in the volume or mass of the liquid.
(2) Changes in temperature and pressure affect them.
(3) In both, molecules are released from the liquid.
(4) Both occur at the surface of the liquid.

Factors affecting evaporation:

(1) Temperature:

- The rate of evaporation increases with temperature.
- In short, as the temperature increases, the rate at which a liquid evaporates also increases.

(2) Air current:

- The stronger the air current, the greater becomes the rate of evaporation.

(3) The suface area of the liquid:

- As the surface area of the liquid increases, the rate of evaporation also increases.

(4) Humidity:

- The lower the humidity, the greater the rate of the evaporation.

N/B: Pressure also affects the rate of evaporation.

The boiling point elevation:

- This is the increase in the boiling point of a liquid, due to the presence of dissolved particles within it.
- For example, the boiling point of water is 100^{0c}, but by dissolving sugar or salt in the water, the boiling will be greater than 100^{0c}.

- This is due to the fact that salt and sugar molecules have greater masses than water molecules (i.e. they are more massive than water molecules), and as a result, the attractive forces are increased when they are added.
- For this reason, more energy in the form of heat will be required to overcome them, causing a rise in the boiling point.
- The boiling point of sea water which is around $104^{0c}$is higher than that of water, since it contains dissolved salt particles, and the increase in the temperature, (i.e. the 4^{0c}) is what is referred to as the boiling point elevation.

Freezing (melting) point depression:

- This is the decrease in the freeing or the melting point of a substance, due to the presence of dissolved particles within it.
- For example, the melting point of ice is 0^{0c}, but the addition of salt to the ice depresses the melting point well below 0^{0c}.

The attainment of the saturated vapour pressure of a liquid:

- Evaporation causes the surface above the liquid to become occupied by vapour molecules.
- These molecules move randomly and on hitting the walls of the container, they bounce off and this exerts vapour pressure on the wall.
- They can also strike the surface of the liquid and re – enter it.
- After some time, the rate at which the molecules leave the liquid becomes equal to the rate at which they enter.
- This attainment of dynamic equilibrium gives the maximum vapour pressure that can be exerted by molecules from the liquid, and it`s known as the saturated vapour pressure.

The reduction in boiling point at higher elevation:

- The atmospheric pressure decreases as we move higher.
- For this reason, the atmospheric pressure at the top of a mountain will be lower than that at the bottom of the same mountain.
- The boiling point of a liquid will be lower on the top of a mountain than that at its bottom.
- This due to the fact that the pressure at the top of the mountain is lower than that at the bottom.
- Consequently, the temperature at which the saturated vapour pressure of the liquid becomes equal to the surrounding atmospheric pressure which is referred to as the boiling point, will be lower on top of the mountain that that at its bottom.

- In short, the boiling point of a liquid decreases with height.

Cooling produced by evaporation:

- Some liquids have low boiling points and as such, they change easily from the liquid into the vapour state at ordinary temperature.
- Such liquids are called volatile liquids and examples are methylated spirit and ether.
- If a little methylated spirit or any volatile liquid is split or placed on the hand, it evaporates quickly and the hand feels very cold.
- In order to change from the liquid into the vapour state, heat is needed by the methylated spirit.
- This heat needed is taken from the hand, causing it to become cold or cool.
- In a similar manner, water will also cause a similar effect but this is less noticeable since water is less volatile.
- Therefore since methylated spirit has a lower boiling point, it evaporates more quickly from the hand than the water.
- It is also a well known fact that milk can be kept cool more efficiently by wrapping its container (i.e. the bottle or the mill can) in wet cloth, rather than allowing it to stand in cold water.
- In this case, as the water evaporates from the wet cloth, it removes heat from the milk causing it to be cold.
- If the rate of evaporation can be increased by placing the milk wrapped in the wet cloth in a draught or moving air, so much the better.
- Sweating or perspiration by the body is a means of losing the excess heat found in a body, so as to maintain a constant temperature (i.e. keep the temperature of the body constant).
- Sweat is produced when the body becomes hot and as it evaporates, heat is taken from the body causing it to cool.
- Lastly dogs which do not perspire from the skin hang out their tongues during hot weather in order to achieve a cooling effect.

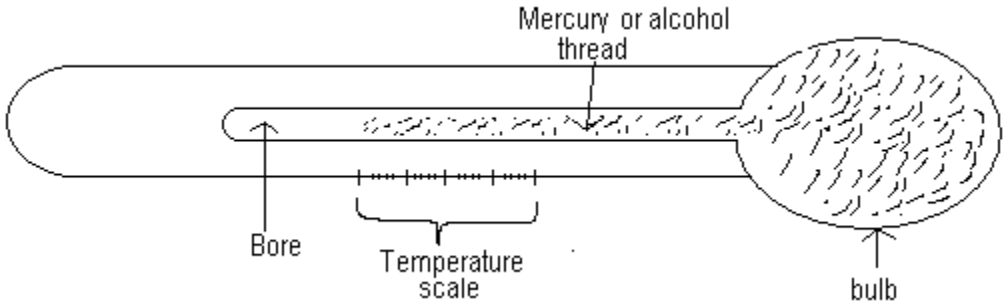
Thermometers: These are devices which are used to measure temperature.

Types of thermometers:

- There are different types and some well known types are:
    (1) Liquid in glass thermometer.
    (2) Thermoelectric thermometer.

(3) Platinum resistance thermometer.
(4) The gas thermometer.
(5) The pyrometer.
(6) Digital thermometer.

Liquid in glass thermometers:



- This type of thermometer contains a liquid and there are two types which are:
  (a) The mercury thermometer.
  (b) The alcohol thermometer.
- The liquid in glass thermometer consists of a glass bulb, which contains a liquid which is either alcohol or mercury.
- This liquid is capable of rising or falling within the bore, as a result of its expansion or contraction.
- It also has a temperature scale.