HEAT

TEMPERATURE

- Temperature is a measure of hotness or coldness of a body
- Temperature is also a measure of thermal equilibrium.
- Ex : kettle with boiling water and box containing ice.

temperature of water T= 100^{o} C

temperature of ice T = 0^{o} C

- Temperature is measured by using thermometer. Many physical properties of materials change with temperature.
- Ex : volume of solid ball(expansion), length of iron rod (expansion)
- The commonly used property is variation of the volume of a liquid with temperature. Liquid–in–glass thermometers mercury, alcohol are used whose volume varies linearly with temperature .
- When hot body touches thermometer ,mercury absorbs the heat and its volume increases and expands. The reading is shown on thermometer.

Temperature is measured commonly in two scales

1.**Fahrenheit scale**

2.Celsius scale.

Ice and steam point (melting point of water ,Boiling point of water)

32 °F and 212 °F - Fahrenheit

0 °C and 100 °C -Celsius scale.

- On the Fahrenheit scale, there are 180 equal intervals between two reference points(MP,BP of water) and on the Celsius scale, there are 100.

- A relationship between Fahrenheit scale and Celsius scale

$$(t_f -32)/180 = t_c /100$$

kelvin scale : absolute zero is based on ideal gas equation.

$$C = K -273$$

Réaumur scale [1] is temperature scale for which freezing and boiling point of water are defined as 0 and 80 R

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{R-0}{80-0} = \frac{K-273.15}{373.15-273.15}$$

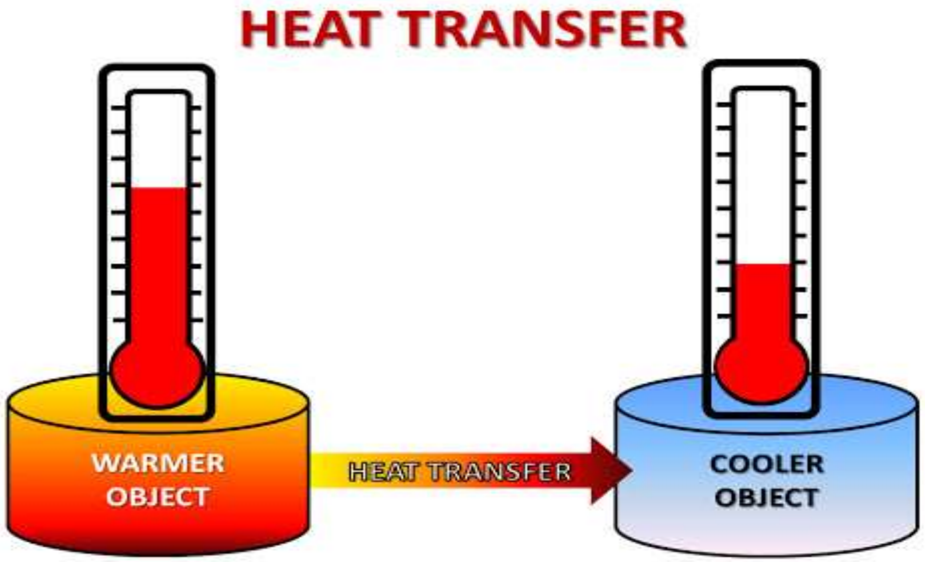
$$\Rightarrow \frac{C}{100} = \frac{F-32}{180} = \frac{R}{80} = \frac{K-273.15}{100}$$

HEAT TRANFER

From hot object to cold objects

t = 100 C → t = 20C

Heat tranfer is mainly due to temperature difference. More temperature difference more heat tranfer



- The SI unit of heat is Joule (J) and CGS unit is calorie (cal).The amount
- of heat required to raise the temperature of 1gram of water by 10C is called
- calorie.
- 1cal = 4.186 Joules
- The SI unit of temperature is Kelvin (K). It can also be expressed as
- degree Celsius (0C).

Thermal equilibrium

- When two bodies are placed in thermal contact, heat energy will be transferred from the ‘hotter’ body to the ‘colder’ body.
- This transfer of heat energy continues till both bodies attain the same degree of hotness (or) coldness. At this stage, we say that the bodies have achieved ‘thermal equilibrium’.
- Thus, the state of thermal equilibrium denotes a state of a body where it neither receives nor gives out heat energy.
- If you are not feeling either hot or cold in your surroundings, then your body is said to be in thermal equilibrium with the surrounding atmosphere.
- The furniture in the room is in thermal equilibrium with air in the room. So we can say that the furniture and the air in the room are at the same temperature.

- **Activity 1**
- Take a piece of wood and a piece of metal and keep them in a fridge or ice box. After 15 minutes, take them out and ask your friend to touch them.

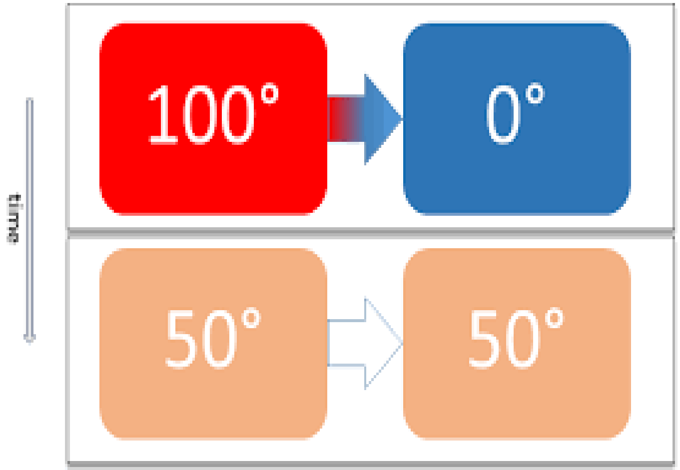
Which is colder? Why?

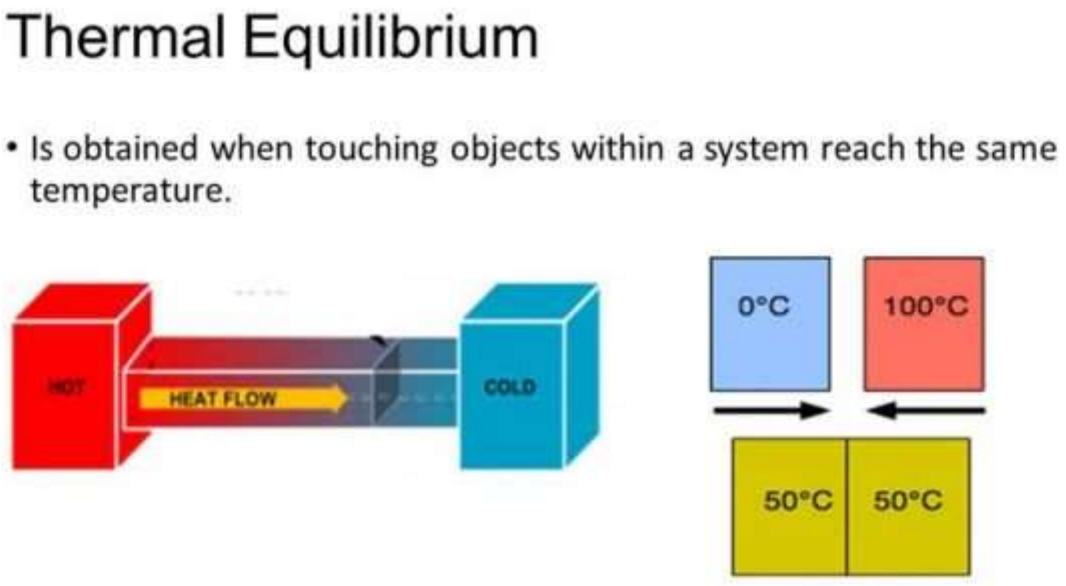
- When we keep materials in a fridge, they become cold i.e., they lose heat energy. The iron and wooden pieces were kept in the fridge for the same period of time but we feel that the metal piece is colder than the wooden piece.

What could be the reason for this difference in coldness?
Does it have any relation to the transfer of heat energy from our body to the object?

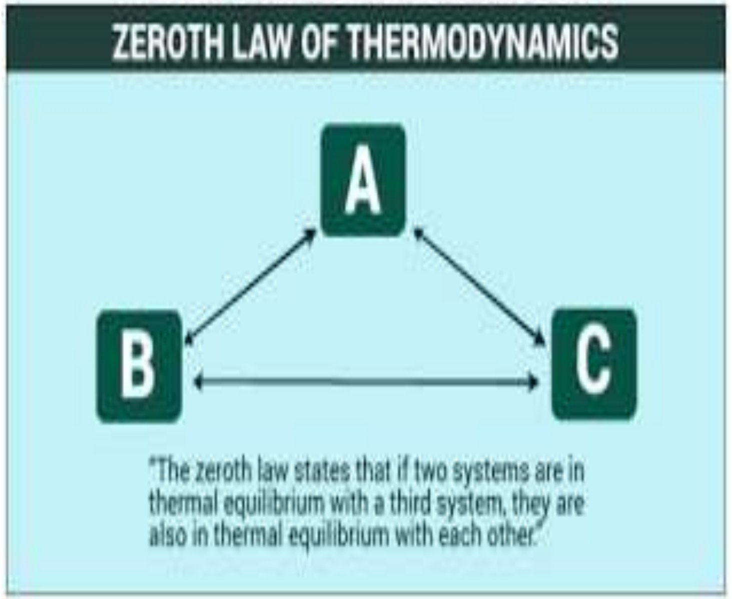
- Heat energy is being transferred from your finger to the pieces. When you remove your finger, you feel of ‘coldness’. This means that heat energy flows out of your body you.
- if you feel that the metal piece is ‘colder’ than the wooden piece, it must mean that more heat energy flows out of your body when you touch the metal piece as compared to the wooden piece.

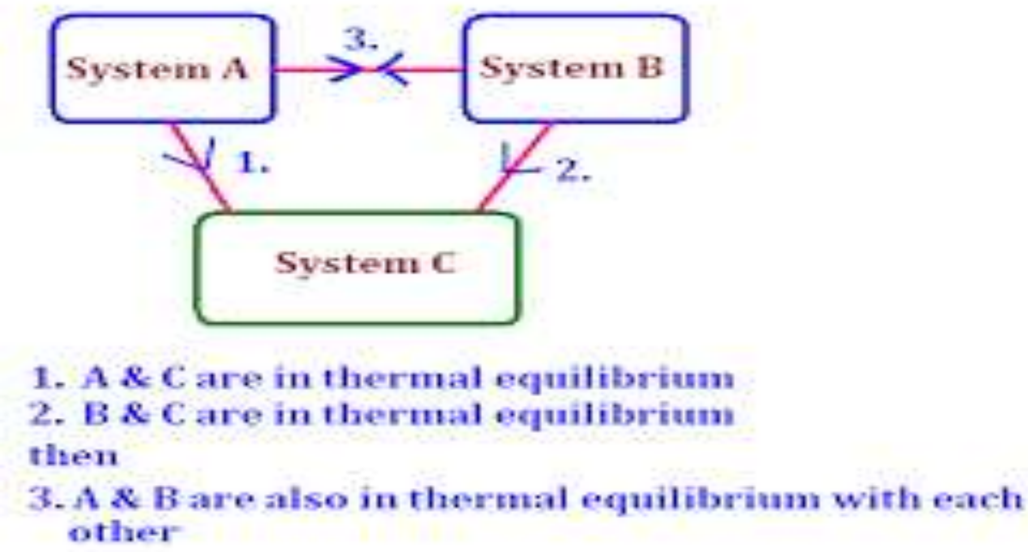
Thermal equilibrium





- “Heat is a form of energy in transit, that flows from a body at higher temperature to a body at lower temperature.”
- The steadiness of the mercury column of the thermometer indicates that flow of heat between the thermometer liquid (mercury) and water, has stopped.
- *Thermal equilibrium* has been attained between the water and mercury. The thermometer reading at thermal equilibrium gives the “temperature”.
- Temperature is a measure of thermal equilibrium.
- If two different systems, A and B in thermal contact, are in thermal equilibrium individually with another system C(thermal contact with A and B), will the systems A and B be in thermal equilibrium with each other?
- We know that if A is in thermal equilibrium with C, they both have the same temperature. Similarly, B and C have the same temperature. Thus A and B will have the same temperature and would therefore be in thermal equilibrium with each other. (A,B and C are in thermal contact).





The SI unit of heat is Joule (J) and CGS unit is calorie (cal).The amount of heat required to raise the temperature of 1gram of water by 1^0C is called calorie.

1cal = 4.186 Joules

The SI unit of temperature is Kelvin (K).

- **Temperature and Kinetic energy**
- Take two bowls one with hot water and second with cold water. Gently sprinkle food colour on the surface of the water in both bowls .Observe the motion of the small grains of food colour.
- Grains of food colour move randomly. This happens because the molecules of water in both bowls are in random motion. We observe that the jiggling of the grains of food colour in hot water is more when compared to the jiggling in cold water.
- bodies has kinetic energy when they are in motion.
- speed of motion of particles in the bowls of water is different, and has kinetic energies. Average kinetic energy of molecules particles of a hotter body is greater than that of a colder body.
- Temperature of a body is an indicator of the average kinetic energy of molecules of that body.
- **“The average kinetic energy of the molecules is directly proportionalto the absolute temperature**”

Specific Heat

- Take a large jar with water and heat it up to 80C.Take two identical boiling test tubes with single-holed corks. One of them is filled with 50g of water and the other with 50g of oil, both at room temperature.
- Insert two thermometers through holes of the corks, one each into two test tubes. Now clamp them to a retort stand and place them in a jar of hot water
- Observe the readings of thermometers every three minutes .
- We believe that the same amount of heat is supplied to water and oil because they are kept in the jar of hot water for the same interval of time.
- We observe that the rate of rise in temperature of the oil is higher than that of the rise in temperature of the water.
- the rate of rise in temperature depends on the nature of the substance.

volume of water in small beaker -250 ml

volume of water in big beaker - 1000ml

- Initial temperature using a thermometer (initial temperatures should be the same).

ts = tb s – small ,b – big

Heat both beakers till the temperature of water in the two beakers rises to 60 C.

Note down the heating times required to raise the temperature of water to 60 C in each beaker.

- more time to raise the temperature of water in the larger beaker when compared to water in the small beaker.
- supply more heat energy to water in a larger beaker (greater quantity of water) than water in a small beaker for same change in temperature.

TEMPARATURE IS CONSTANT T = 60 c

- For same change in temperature the amount of heat (Q) absorbed by a substance is directly proportional to its mass (m)

  $Q \propto m$ (when ΔT is constant)

Now take 1 litre of water in a beaker and heat it over a constant flame.

- Note the temperature changes (ΔT) for every two minutes.
- change in temperature rise with time is constant,
- for the same mass (m) of water the change in temperature is proportional to amount of heat (Q) absorbed by it.

  $Q \propto \Delta T$ (when ‘m’ is constant

  $Q \propto m\Delta T$ $Q = mS\Delta T$

  Where ‘s’ is a constant for a given substance. This constant is called “specific heat” of the substance.

$S = Q/m\Delta T$

- The specific heat of a substance is the amount of heat required to raise the temperature of unit mass of the substance by one unit.

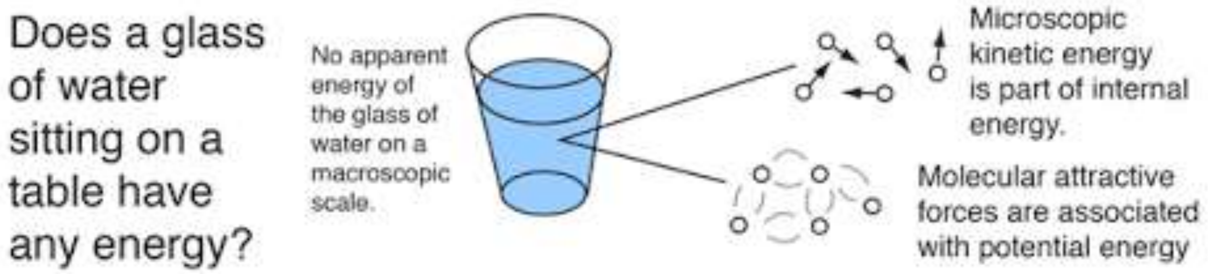
  CGS unit of specific heat is cal/g-C

  SI unit of it is J / kg - K

  1 cal/g- C = 1 kcal /kg-K = 4.2 x 1000 J/kg-K

- specific heat of a substance depends on its nature.
- If the specific heat is high, the rate of rise (or fall) in temperature is low for same quantity of heat supplied. It gives us an idea of the degree of ‘reluctance’ of a substance to change its temperature.
- The temperature of a body is directly proportional to the average kinetic energy of particles of the body.The molecules of the system have different forms of energies such as linear kinetic energy, rotational kinetic energy, vibrational energy and potential energy between molecules. The total energy of the system is called *internal energy* of the system.

- When we supply heat energy to the system the heat energy given to it will be shared by the molecules among the various forms of energy.
- This sharing will vary from substance to substance. The rise in temperature is high for a substance, if the maximum share of heat energy is utilized for increasing its linear kinetic energy.
- This sharing of heat energy of the system also varies with temperature .That is why the specific heat is different for different substances.



- **Applications of Specific heat capacity**
- 1. The sun delivers a large amount of energy to the Earth daily. The water sources on Earth, particularly the oceans, absorb this energy for maintaining a relatively constant temperature. The oceans behave like heat “store houses” for the earth. They can absorb large amounts of heat at the equator without appreciable rise in temperature due to high specific heat of water.. Therefore, oceans moderate the surrounding temperature near the equator. Ocean water transports the heat away from the equator to areas closer to the north and south poles. This transported heat helps moderate the climates in parts of the Earth that are far from the equator.water has an ability to resist sudden changes in temperature. Because of this, water is said to have a high specific heat. Because water absorbs and releases heat at a rate much slower than land, air temperatures in areas near large bodies of water tend to have smaller fluctuations..
- Water melon bought out from the refrigerator retains its coolnessfor a longer time than any other fruit because it contains a large percentage of water. (water has greater specific heat).
- A samosa appears to be cool outside but it is hot when we eat it because the curry inside the samosa contains ingredients with higher specific heats.

- **Method of mixtures**

Situation – 1: Take two beakers of the same size and pour 200 ml of water in each of them. Now heat the water in both beakers till they attain the same temperature. If you pour this water from these two beakers into a larger beaker, what temperature could you expect the mixture to be? Measure the temperature of the mixture.

ANSWER: beakers are at same temperature …mixture temperature is same as beaker

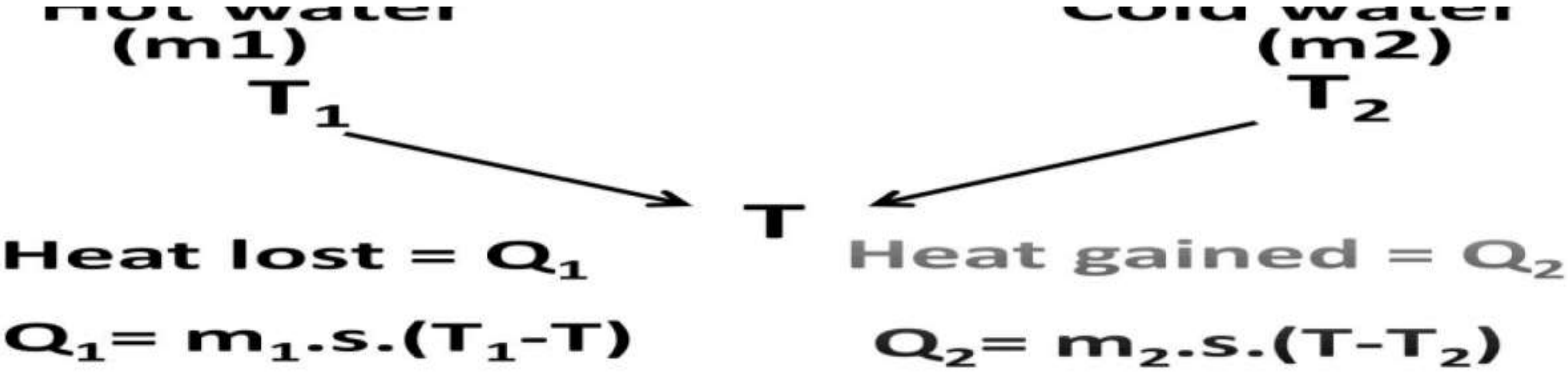
- **Situation – 2:** Now heat the water in one beaker to 90oC and the other to 60oC . Mix the water from these beakers in a larger beaker. temperature of the mixture be? Measure temperature of the mixture. What did you notice?

temperature of mixture is higher than cold one lower than hot one

- **Principle of method of mixtures**
- When two or more bodies at different temperatures are brought into thermal contact, then net heat lost by the hot bodies is equal to net heat gained by the cold bodies until they attain thermal equilibrium. (If heat is not lost by any other process)

Net heat lost= Net heat gain

- This is known as **principle of method of mixtures.**



- **Situation – 3:** Now take 100 ml of water at 90C and 200 ml of water at 60C and mix the two.

  Let the initial temperatures of the samples of masses m1 and m2 be T1

  and T2 (the higher of the two temperatures is called T1, the lower is called(T2).

  Let T be the final temperature of the mixture. (T1 high than T2)

The amount of heat lost by the hotter sample Q1 = m1S(T1- T).

The amount of heat gained by the cooler sample Q2 = m2S(T - T2).

heat lost by the hotter sample is equal to the heat gained by the cooler sample (assuming no loss of heat)

$$Q1 = Q2$$

$$m1S(T1 - T) = m2S(T - T2)$$

$$T = (m1T1 + m2T2)/(m1 + m2)$$

T1 → T ← T2

cool body hot body

heat lost by hot body = heat gained by cool body

cool body gains temperature T - T1

Hot body lost temperature T2 – T

- **Activity 8**

  Evaporation
- Take a few drops of spirit (say 1 ml) in two petri dishes.
- Keep one of the dishes containing spirit under a ceiling fan and switch on the fan . Keep another dish with its lid closed. Observe the quantity of spirit in both dishes after 5 minutes.
- spirit in the dish that is kept under the ceiling fan disappears, where as you will find some spirit left in the dish that where as you will find some spirit left in the dish that is kept in the lidded dish
- The molecules of spirit that is kept in petri dish, continuously move with random speeds in various directions. As a result these molecules collide with other molecules.
- During the collision they transfer energy to other molecules. When the molecules inside the liquid collide with molecules at the surface, the molecules at the surface acquire energy and may fly off from the surface.
- Some of these escaping molecules may be directed back into liquid when they collide with the particles of air. If the number of escaping molecules is greater than the number returned, then the number of molecules in the liquid decreases. Thus when a liquid is exposed to air, the molecules at the surface keep on escaping from the surface till the entire liquid disappears into air. This process is called *evaporation.*

Evaporation is a surface phenomenon.

- Since the kinetic energy of a molecule is proportional to its temperature, evaporation proceeds more quickly at higher temperatures. As the faster-moving molecules escape, the remaining molecules have lower average kinetic energy, and the temperature of the liquid decreases. This is why evaporating sweat cools the human body.

- Rate of evaporation of a liquid depends on its surface area, temperature amount of vapour already present in the surrounding air.

Evaporation is cooling process

- During the process of evaporation, the energy of the molecules inside
- the liquid decreases and they slow down. They transfer this energy to
- escaping molecules during the collisions.
- Let us determine the reason for faster evaporation of spirit kept under the fan. If air is blown over the liquid surface in an open pan or perti dish, the number of molecules returned is reduced to a large extent. This is because any molecule escaping from the surface is blown away from the vicinity of the liquid.
- This increases the rate of evaporation. This is the reason why the spirit in petri dish, that is kept under ceiling fan evaporates quickly when compared to that kept closed. You will notice that clothes dry faster when a wind is blowing.

- **Condensation** is the change of the physical state of matter from the gas phase into the liquid phase, and is the reverse of vaporization. It can also be defined as the change in the state of water vapor to liquid water when in contact with a liquid or solid surfac
- Place a glass tumbler on the table. Pour cold water up to half its height.
- We know that the temperature of surrounding air is higher than the temperature of the cold water.
- Air contains water molecules in the form of vapour.
- When the molecules of water in air, during their motion, strike the surface of the glass tumbler which is cool; they lose their kinetic energy which lowers their temperature and they get converted into droplets.
- The energy lost by the water molecules in air is gained by the molecules of the glass tumbler.
- Hence the average kinetic energy of the glass molecules increases. In turn the energy is transferred from glass molecules to the water molecules in the glass.
- In this way, the average kinetic energy of water molecules in the

tumbler rises. Hence we can conclude that the temperature of the water in

glass increases. This process is called ‘*condensation*’.

It is a warming process.

- You feel warm after you finish your bath under the shower on a hot
- day. In the bathroom, the number of vapour molecules per unit volume is greater than the number of vapour molecules per unit volume outside the bathroom.
- When you try to dry yourself with a towel, the vapour molecules surrounding you condense on your skin and this condensation makes you feel warm
- **Humidity**

Some vapour is always present in air. This vapour may come from evaporation of water from the surfaces of rivers, lakes, ponds and from the drying of wet clothes, sweat and so on. The presence of vapour molecules in air is said to make the atmosphere humid. The amount of water vapour present in air is called *humidity*

- **Boiling**
- Take a beaker of water, keep it on the burner .Note the readings of
- thermometer for every 2 minutes.
- You will notice that, the temperature of the water rises continuously,
- till it reaches 100°C. Beyond 100°C no further rise of temperature of
- water is seen. At 100 0C, though supply of heat continues, the temperature
- does not increase further. We also observe a lot of bubbling at the surface
- of water at 1000C. This is what we call *boiling* of water

- **Dew and Fog**
- In early morning, during winter, you might have noticed that water droplets form on window panes, flowers, grass etc.

- During winter nights, the atmospheric temperature goes down. The surfaces of window-panes, flower, grass etc, become still colder. The air near them becomes saturated with vapour and condensation begins. The water droplets condensed on such surfaces are known as ***dew.***
- If the temperature falls further, the whole atmosphere in that region contains a large amount of vapour. So the water molecules present in vapour condense on the dust particles in air and form small droplets of water. These droplets keep floating in the air and form a thick mist which restricts visibility. This thick mist is called ***fog***.

Water is a solution, there are many impurities dissolved in it including some gases. When water or any liquid is heated, the solubility of gases it contains reduces. As a result, bubbles of gas are formed in the liquid (at the bottom and on walls of the vessel).

Evaporation of water molecules

from the surrounding causes these bubbles, to become filled with saturated vapour, whose pressure increases as we increase the temperature of the liquid by heating.

At a certain temperature, the pressure of the saturated vapour inside the bubbles becomes equal to the pressure exerted on the bubbles from the outside (this pressure is equal to the atmospheric pressure plus the pressure of the layer of water above the bubble).

As a result, these bubbles rise rapidly to the surface and collapse at the surface releasing vapour present in bubbles into air at the surface. This process of converting the liquid into vapour (gas) continues as long as you supply

- Boiling is a process in which the liquid phase changes to gaseous
- phase at a constant temperature at a given pressure." This temperature is
- called boiling point of the liquid.
- Are the processes of evaporation and boiling the same?
- As you have seen in activity – 8 and 10, the boiling of a liquid differs
- essentially from evaporation. Note that evaporation takes place at any
- temperature, while boiling occurs at a definite temperature called the
- boiling point. Let us recall your observation in activity – 10 that, when
- boiling process starts, the temperature of the liquid cannot be raised further,
- no matter how long we continue to heat it. The temperature remains constant
- at the boiling point until all of the liquid has boiled away.
- In activity – 10, you have noticed that, while heating the water in the
- beaker, the temperature of water rises continuously till it reaches 100 0C.
- But once boiling got started, no further rise of temperature is seen though
- supply of heat continues.
- • Where does the heat energy supplied go?
- This heat energy is used to change the state of water from liquid to
- vapour (gas). This is called *latent heat of vapourization.*
- The heat energy required to change 1gm of liquid to gas at constant

- temperature is called latent heat of vapourization.
- Consider a liquid of mass ‘m’ that requires heat energy of ‘Q’ calories
- to change from its state from liquid phase to gas phase. Then ***Latent heat***
- ***of vaporization*** is **Q/m**. Latent heat of vaporization is denoted by ‘**L**’.
- CGS unit of latent heat of vaporization is cal/gm and SI unit is J/kg.
- The boiling point of water at constant atmospheric pressure (1atm) is
- 100°C or 373K and Latent heat of vaporization of water is 540 cal/gm.
- **Melting**
- Take small ice cubes in a beaker. Insert the thermometer into ice cubes
- in the beaker. Observe the reading of the thermometer. Now start heating
- the beaker keeping it on a burner. Observe changes in the thermometer
- reading every 1 minute till the ice completely melts and gets converted
- into water.
- You will observe that the temperature of ice at the beginning is equal
- to or below 0oC. If the temperature of ice is below 0oC, it goes on changing
- till it reaches 00C. When ice starts melting, you will notice no change in

• Why does this happen?

The heat energy supplied to the ice increases the internal energy of the molecules of the ice. This increase in internal energy of molecules weakens the bonds as well as breaks the bonds between the molecules (H_2O) in the ice. That is why the ice (in solid phase) becomes water (in liquid phase).This process takes place at a constant temperature 0°C or 273K. This temperature is called *melting point.*

This process of converting solid into a liquid is called "***Melting***".

The temperature of the ice does not change during melting because the heat energy given to the ice is totally utilized in breaking the bonds between the water molecules.

The process in which solid phase changes to liquid phase at a constant temperature is called melting. This constant temperature is called melting point.

- How much heat energy is required to convert 1gm of ice to liquid?
- The Heat energy required to convert 1gm of solid completely into
- liquid at a constant temperature is called *Latent heat of fusion.*
- Consider a solid of mass m. Let heat energy Q be required to change it
- from the solid phase to liquid phase. The heat required to change 1gm of
- solid into liquid is Q/m.
- Latent heat of fusion L = Q/m. The value of Latent heat of fusion of
- ice is 80cal/gm

- **Freezing**
- You might have observed coconut oil and ghee getting converted from
- liquid state to solid state during winter season.
- • What could be the reason for this change?
- • What happens to water kept in a refrigerator?
- • How does it get converted from liquid phase to solid phase?
- We know that the water that is kept in a refrigerator converts to solid
- ice. You know that initial temperature of water is more compared to the
- temperature of ice. It means that during the process of conversion from
- liquid to solid, the internal energy of the water decreases so that it becomes
- a solid ice. This process is called *freezing*.
- “The process in which the a substance in liquid phase changes to solid
- phase by losing some of its energy is called *freezing*.”
- Freezing of water takes place at 0°C temperature and at one
- atmospheric pressure.
- • Are the volumes of water and ice formed with same amount of water
- equal? Why?

- We know that the volume of the water poured into the glass bottle is
- equal to the volume of the bottle. When the water freezes to ice, the bottle
- is broken .This means that the volume of the ice should be greater than the
- volume of the water filled in the bottle.
- In short, we say that water ‘expands’ (increases in volume) on freezing!
- Thus the density of ice is less than that of water and this explains why
- ice floats on water.