Chapter 7

HEAT AND TEMPERATURE

We often use the words like 'hot' and 'cold' in our daily life. We feel hot when we sit in the sunlight or in front of fire. We feel cold when we put a piece of ice on our palm. Have you ever thought why this happens?

Heat is a kind of energy that transfers from an object at a higher temperature to the colder object. In the first example energy enters our body either from the sun or the fire. That's why we feel hot. While in the second case energy moves from our body to the piece of ice. That's why we feel cold.

"The energy flow which makes an object appear hot or cold to us is called heat."

7.1 Heat, a kind of energy

Our palms become hot when they are rubbed together and iron becomes hot on being beaten with a hammer. In both these cases mechanical energy is being converted into heat energy or we can say that the heat energy is increasing. When a candle burns, chemical energy gets converted into heat energy. While in an electric heater, electrical energy gets converted into heat.

In the above examples, different kinds of energy are being converted in to heat. In the same way heat energy can also be converted into other forms of energy. You may have heard that in a thermal power station, heat energy is converted into electrical energy. In a steam engine, heat energy is converted into mechanical energy which helps in moving the engine. Food eaten by us keeps our body warm and gives us energy for doing different kinds of work. Can you give examples where heat energy gets converted into other forms of energy and vice versa?

Let us, try to understand the different stages of water being heated through an experiment.

Activity - 1

Materials required :- Hot water, cold water, luke warm water and three tubs.

Take hot water in one tub, cold water in the second tub and luke warm water in the third one. Dip your left hand in hot water and right hand in cold water for about half a minute. Now dip both hands together in the luke warm water (fig. 7.1). What do you feel?

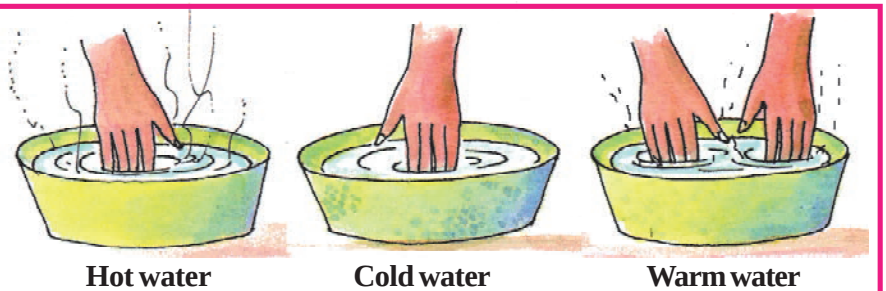


Fig. 7.1

The water is same but the left hand fingers feel it is cold while the right hand fingers feel it is hot. Why is it so? This implies that it is not possible to guess the temperature of a substance on the basis of feeling only. It is certain that water in different tubs has different degree of hotness, that can be measured only by finding their temperatures with a thermometer.

"The physical parameter used to compare the hotness of the objects is called temperature." or "the temperature of an object is the measure of thermal stage that determines the direction of flow of heat energy."

7.2 Effects of heat

We see different effects of heat in our daily life. When two objects are brought in contact then heat energy flows from the object at higher temperature to the object at lower temperature until temperature of both objects become equal. Though we cannot see the flow of heat yet the effect of the flow of heat on different objects can definitely be felt. Some effects of heat are as follows-

(1) Increase in temperature :- we will be able to see this effect through activity-2.

Activity - 2

Materials required :- Test tube, water, thermometer, candle and a stand.

Take some water in a test tube. Measure its temperature with a thermometer. Light a candle and use it to heat the test tube from below. After some time note the temperature of the water again (fig. 7.2). Has the temperature of water in the test tube increased? What could be the reason for this rise?

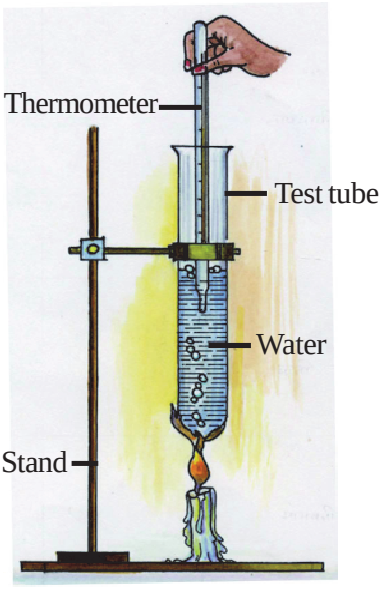


Fig. 7.2 Increase in temperature due to heat

(2) Expansion :-

Most of the solids, liquids and gases expand on heating and contract on cooling. Let us understand this with the help of some activities.

(a) Expansion in solids

Activity - 3

Materials required :- a ball and a ring apparatus, some arrangement for heating.

The diameter of the ring in the ball and ring apparatus is just enough for the ball made of metal to pass through it, (fig. 7.3(a)). Heat this ball for sometime and keep it over the ring. Can the ball still pass through the ring? If not (fig. 7.3(b)) then think about why this happens?

Some examples of thermal expansion in solids from our daily life are given below-

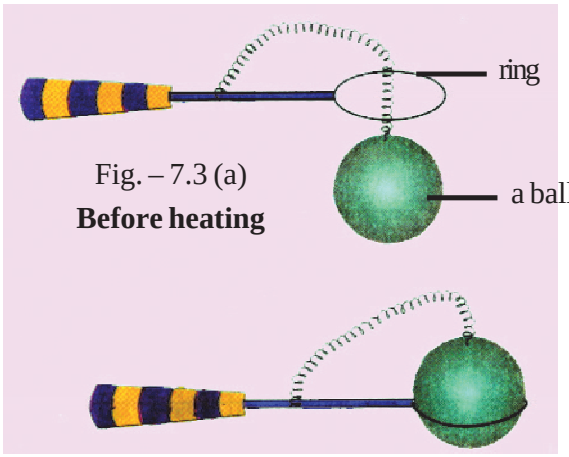


Fig. – 7.3 (a)
Before heating

After heating
Fig. – 7.3 (b)

(1) If the lid of a glass bottle becomes tight and we dip the lid in hot water by turning the bottle up side down, then the lid opens as it becomes loose due to thermal expansion.

(2) An iron ring is fixed over the wooden wheel of a bullock cart. For this the ring is made a bit smaller than the wooden wheel. Before fixing it over the wheel, it is heated so that it expands and go over the wheel. On cooling it contracts and tightly fits the wooden wheel.

(3) When boiling water is poured into a thick glass tumbler, the tumbler breaks, as the expansion of the inner surface of the tumbler is more than that of the outer surface.

(4) In summer the wires of telephone and electricity between two poles are kept some what longer and hanging in the middle so that they do not shrink and break in winters.

(b) Expansion of Liquids -

Activity - 4

Materials required :- A glass test tube, a cork having one hole fitted with a glass tube, red ink, arrangement for heating.

Fill the glass test tube up to the top with water. Add two drops of red ink into the water. Fix the cork, with a tube fitted the mouth of the test tube. Some water will rise in to the tube. Mark the level of water in the tube. Now heat the test tube and mark the water level in the tube again. You will see that the level of water in the tube rises. If we stop heating then the water level comes down. What is the reason?

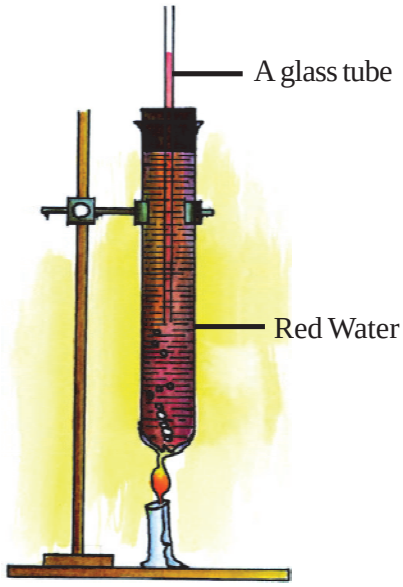


Fig. – 7.4 Expansion in liquid

As water expands on heating so does mercury. Mercury, is the only metal that is liquid at room temperature. It is used as the liquid for indicating temperature in the thermometer.

Some examples of thermal expansion in liquids are as follows –

(1) When the bulb of a thermometer is dipped in hot water, the mercury in the bulb rises due to thermal expansion. On taking the thermometer out of water, the mercury shrinks in to the bulb again.

(2) For cooling the engines of motor cars, water in the radiator is not filled up to the top. There is a danger of the radiator bursting due to water expansion from the heating of the engine.

(c) Expansion of gases :– We discussed the thermal expansion of solids and liquids. Let us now observe whether gases show the same behaviour?

Activity - 5

Materials required :- A test tube, a cork having one hole fitted with a glass tube, an arrangement for heating, a rubber tube.

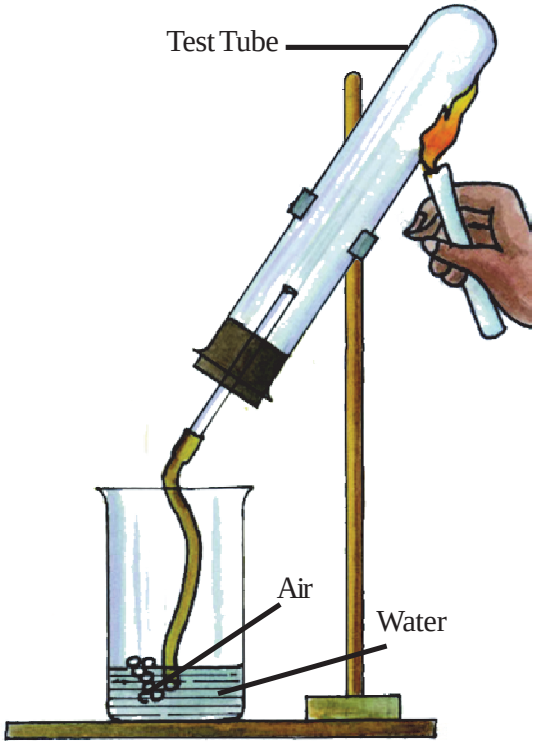


Fig. – 7.5 Expansion of air

Fit the cork, having the tube, on the mouth of the test tube. Attach a rubber tube at the mouth of the glass tube fitted in the test tube. Place the test tube up side down such that the top of the rubber tube remains inside the water taken in a beaker (fig. – 7.5). Heat the test tube with the help of a candle. You will see that some of the air in the test tube comes out as the bubbles in water. Why do the air bubbles come out? Stop heating the test tube. You will see that the air in the test tube shrinks on getting cooled and to take its place water starts entering the test tube through the tube. Thermal expansion in gases can also be understood by the following examples–

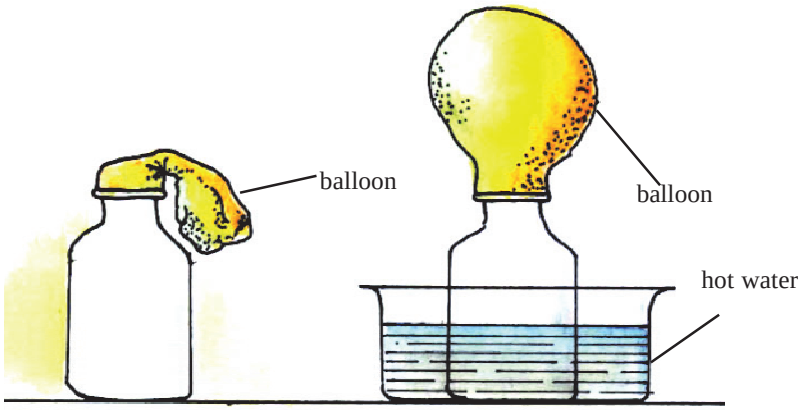


Fig. – 7.6 Expansion in gases on heating

(i) Attach a balloon to the mouth of a bottle. On keeping the bottle in the tub of hot water, the balloon expands (fig. – 7.6). The reason for this is the thermal expansion of air inside the bottle.

(ii) The tyres of vehicles burst in summer days.

(iii) *Poori* and *Chapatti* expand on being heated.

This way we see that solids, liquids and gases expand on heating and shrink on cooling. The expansion in solids is less than that in liquids and expansion in gases greater than that in liquids or in other words we can say that on heating, expansion in gases is much more than the expansion of liquids..

Answer these

1. If we touch an object and it feels cool then what is the direction of flow of heat.
2. Write solid, liquid and gas in order of the extent of their thermal expansion.
3. Give the method, with reason for opening the tight lid of a glass bottle.
4. There are chances of a bicycle tube bursting when placed in the sun. What could be the reason for this?

7.3 Change of state

All materials in nature are made up of molecules that are always in motion. In solids molecules are arranged in an orderly manner with fixed positions. These molecules keep vibrating around their mean positions. Molecules of solids do not have the freedom to leave their positions due to the intermolecular force of attraction between them. The intermolecular force between molecules of gases is very small. That's why they are far apart. They are free to move any where and are in continuous motion. Molecules of the liquid are closer to each other than those of a gas. Therefore the intermolecular force between them is less in comparison to that in a solid and

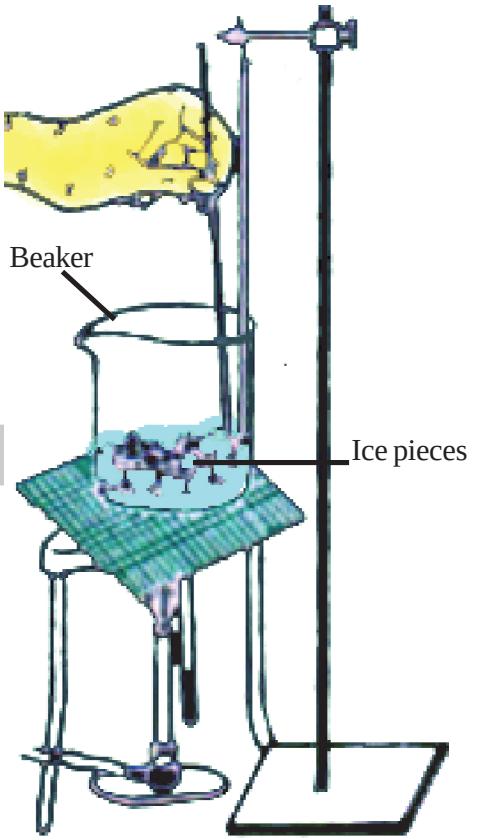


Fig. – 7.7 Change of state

is greater in comparison to that in a gas. So these molecules move within the boundary of the liquid. Since heat is a form of energy, on heating, the energy and motion of molecules get increased. This is the reason for the solids being converted in to liquids and liquids in to gases when heated. Similarly, on cooling, the energy and motion of molecules in materials decreases and because of this gases get converted to liquids and liquids to solids. All these changes are called change of state.

Let us understand this by an activity.

Activity - 6

Materials required :- Beaker, tripod stand, thermometer, wire gauze, ice pieces, glass rod, arrangement for heating.

Break ice into pieces (approx. 300 g) and keep them in a beaker. Now place the beaker on the wire gauze kept on a tripod stand and heat it. Note the temperature of the beaker after every 1 minute and write the observations in table 7.1. During this period keep shaking the ice with a glass rod (fig. – 7.7).

Table - 7.1

S. No.	Time	State of matter	Temperature
1.	0 Minute	Solid	0^0C
2.	1 Minute	Solid and some liquids	0^0C
3.	2 Minute	Solid and some liquid	0^0C
4.	3 Minute	----------	----------
5.	----------	----------	----------
6.	----------	----------	----------
7.	----------	----------	----------

We observed that the temperature remains at 0°C until the entire ice melts. (fig. -7.7). Where has the heat given to the beaker and the ice during this period gone? This heat is used in changing the state of ice or should we say that this heat is consumed in making the intermolecular forces weaker.

"The fixed temperature at which a material changes its state from solid to liquid is called its melting point."

Similarly, "each liquid gets converted to a solid at some fixed temperature. During this process, the temperature of the liquid remains fixed even while it gives up heat. This fixed temperature is called the freezing point of that material"

Any solid material when given heat energy at its melting point, changes into its liquid form. While on taking away heat from the liquid, at its freezing point, to the same extent makes the liquid return to its solid form.

The melting and freezing points of any material are always the same. For example, water freezes if it is cooled at 0°C and ice melts if it is heated above 0°C.

Table - 7.2

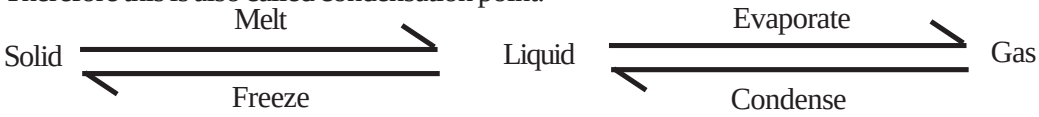
S. No.	Name of the substance	Melting point / Freezing point
1.	Mercury	-39 °C
2.	Ice	0 °C
3.	Lead	327 °C
4.	Gold	1063 °C

The Minus sign denotes that the temperature 39^0c is lower than 0^0c

In the above activity, if we keep on heating the water for a long time, then its temperature will increase till it starts boiling. At this stage the water starts changing in to steam. While the state is changing even if the water is heated more, its temperature will not increase.

"The temperature at which a liquid starts boiling and changes to its gaseous state is called its boiling point."

At the same temperature the vapour of the liquid or the gaseous form condenses to its liquid state. Therefore this is also called condensation point.



Different liquids have different boiling points. The boiling points of some materials are given in the table -7.3.

Table - 7.3

S. No.	Name of matter	Boiling point (^{0}C)
1.	Wax	54
2.	Water	100
3.	Mercury	357
4.	Zinc	907
5.	Copper	2336

Some examples of change of state -

1. The heat energy given to boiling water goes into steam. This is the reason why steam burns us more in comparison to boiling water.
2. When a piece of ice is put into a sherbat then the sherbat becomes cooler because ice takes energy from the sherbat to change its state.
3. The temperature of the atmosphere decreases after snowfall. This is because snow absorbs heat from the atmosphere to melt and return to its liquid form.

7.4 Chemical and biological changes

Many chemical changes are possible only on heating. When we mix iron pieces with sulphur powder, no chemical reaction takes place. When we heat this mixture, then iron sulphide is formed. Similarly oxygen is released when we heat potassium chlorate and potassium permagnate.

Heat energy is produced in some chemical changes. For example, on mixing lime stone with water, on putting sodium in water or on mixing water with sulphuric acid.

Besides chemical changes, heat energy is responsible for biological changes also. We all know that in summer, milk and other edible things get stale and spoil quickly. Bacteria responsible for spoiling these become more active at temperatures (30^0C to 45^0C). But if these things are heated up to 60^0C or beyond, then many bacteria are killed. That's why in summers we need to boil the milk several times in order to save it from spoiling. Fruits, milk and food etc. are kept in refrigerators at low temperatures in order to save them from spoiling because bacterias die at very low temperatures also.

37^0C temperature is suitable for the mammal cells and 40^0C for birds. This is the reason that for the development of eggs, it is necessary to warm them and keep them at a comfortable and steady temperature.

Answer these

1. Why does the melting and freezing of a material take place at the same temperature?
2. Doctors clean the skin with spirit before giving an injection. Why does that place feel cold?
3. During summers, water in a pitcher made up of smooth black soil does not become as cool as the pitcher made of red soil (having small pores). Why?
4. To save milk from going stale we boil it many times or keep it in the refrigerator. Why?

7.5 Measurement of heat

We have studied that heat is an energy whose effect causes the temperature of an object to increase. This property is used to measure the heat energy. SI unit of heat energy is joule. Other units of heat energy are calorie and kilocalorie.

"One calorie heat is the amount of heat that increases the temperature of 1g of water by 1^oC."

1 calorie = 4.186 joule

and 1000 calorie = 1 kilo calorie

"One kilocalorie heat is the amount of heat that raises the temperature of 1 kg of water by 1^oC."

7.6 Specific heat capacity

Let us think about the factors that govern the amount of energy to be absorbed by the body for increasing its temperature. Experiments show the thermal energy required to heat an object depends on the following factors -

(a) Mass of the object (m) - larger the mass of the object, higher the required thermal energy for increasing the temperature by a fixed amount.

(b) Extent of the change in temperature (t)- higher the increase in temperature, larger is the thermal energy needed.

(c) Nature of the material of the object - to increase the temperature by the same amount, objects of different materials, with equal mass, require different amounts of thermal energy. This energy needed depends on the nature of the material.

Metals and oils heat up faster in comparison to water. It means that to increase the temperature of these objects by the same amount we require less thermal energy than for water. We call this property of materials as their specific heat capacity.

"The amount of thermal energy required to raise the temperature of one kg of a material by 1^oC is called the specific heat capacity of the material."

The unit of specific heat capacity is joule / kg^{o}C or joule per kilogram degree celsius.

The specific heat capacities of some materials are given in the following table.

Table - 7.4

S.No.	Substance	Specific heat capacities (Joule / kg ^{O}C)
1.	Water	4185
2.	Ice	2060
3.	Glass	840
4.	Iron	450
5.	Copper	386
6.	Mercury	140
7.	Lead	128

Effect of high specific heat capacity of water-

From the above table we see that water has the maximum heat capacity. It means that to increase the temperature of water by a fixed amount, we need the largest amount of thermal energy. It also releases the largest amount of energy while cooling. That is why-

1. Water is used as a cooling agent in engines of vehicles.
2. Warm water is used in bottles for massaging.
3. Deserts quickly become hot during day time and also quickly cool down at night. While sea water heated by sunlight during the day time does not cool at fast. At night when the atmosphere starts cooling, coastal areas remain hot due to the thermal energy released by sea water.

We have seen above that the specific heat capacity of any material is its special characteristic property. Different masses of the same materials need different amount of thermal energy for equal temperature increase. This property of the object is known as its heat capacity.

"The required thermal energy for increasing the temperature of an object of any substance by 1^{o}C is called the heat capacity of the object."

To heat the object, the required amount of thermal energy depends on its mass, specific heat capacity and increase in its temperature.

The amount of thermal energy required for an object to increase its temperature by t^{o}c is Q = m s t.

Q = mass x specific heat capacity x change in temperature

Example -

The required thermal energy for increasing the temperature of an object made of copper having a mass 100 kg by 10^{o} C is

Q = 100 kg x (386 joule / kg^{0}C) x (10^{0}C) = 386000 joule = 3.86 x 10^{5} joule

In the above example if the same copper object is cooled by 10^{0}C then it will release 3.86 x 10^{5} joules of thermal energy.

7.7 Thermometer

We can sense whether the object is hot or cold by touching them but it is not possible to find the value of the accurate temperature by this. Therefore for measuring temperature we use an instrument called the Thermometer. We have all seen the thermometer (fig. 7.8). This is a tube made up of thick glass having a narrow hole (capillary) of uniform diameter in it.

One end of the tube has a bulb made of thin glass filled with mercury. The other end of the glass tube is sealed after removing air from it. Temperature divisions in Celsius or in some other unit are marked on

the tube. The SI unit of temperature measurement is degree Celsius. In the thermometer, mercury is generally used as the liquid for temperature measurement. The reasons for this are as follows –

1. Mercury is a shining and non-transparent liquid, this means it can be seen very easily from the outside of the glass.
2. It does not stick to the glass walls.
3. It remains in the form of a liquid for a large range of temperatures (freezing point -39°C and boiling point 357°C).
4. Its rate of expansion remains the same for almost all temperature.

In a thermometer, divisions are marked from 0°C (freezing point of water) to 100°C (boiling point of water). Look at your thermometer and find its least count (Least count is the minimum temperature change that can be measured).

The bulb of the thermometer needs to be in close contact with the object whose temperature we wish to find. To find the temperature of your palm, place the bulb of the thermometer in contact with the palm and see the mercury rise. When the mercury stops rising and its level become steady, note the position of its upper end. This is the temperature of your palm.

Find the temperature of your room. Find the temperature shown by the thermometer in Sunlight and in shadow. Now you could understand the usefulness of an umbrella in Sunlight. Use the school thermometer and note the temperature in your school daily.

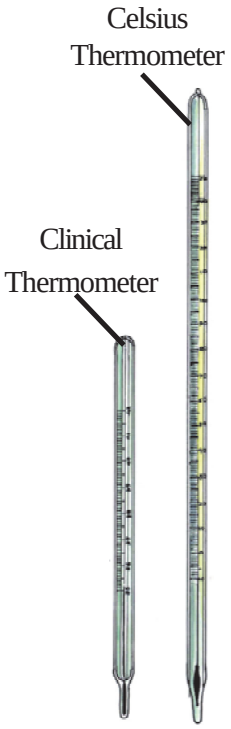


Fig. 7.8 Thermometer

7.7.1 Precautions using thermometer-

You all are familiar with thermometer and had learnt about it. Let's see the precautions to be taken while reading a clinical thermometer:-

- Thermometer should be washed before and after use, preferably with an antiseptic solution.
- Ensure that initially the mercury level is below 30°C.
- Read the thermometer keeping the level of mercury along the line of sight. (at eye level)
- Handle the thermometer with care. If it hits against some hard object, it may break.
- Don't hold the thermometer by the bulb while reading it

In Libia (Africa) on a particular day in the year 1922 it became so hot that the temperature of air even in shade was as high as 58°C. At some places in Chhatisgarh the maximum temperature of air sometimes reaches 48°C and more. When it is so hot we feel extremely uncomfortable as the normal temperature of the human body is 37°C. The minimum temperature of air in the world has been measured to be -89°C in the Antarctica continent. The use of the negative sign shows that this temperature was 89°C below 0°C (the freezing point of water). In winters when the atmospheric temperature around us becomes 15°C – 20°C, we begin to feel a bit cold.

Answer these

1. Give the definitions of calorie and kilocalorie and write the relation between them.
2. On what factors does the amount of heat required to raise the temperature of an object up to some fixed temperature depend?
3. Mercury is supposed to be the most suitable liquid for measuring temperature. Why?

We have learnt

- Heat is a form of energy.
- The measure of the degree of hotness of an object is called its temperature. Higher or lower temperature fixes the direction of heat flow.
- The effects of heat are – increase in temperature, area or volume, change of state and chemical and biological changes.
- Solid, liquid and gas all expand by taking heat.
- On being heated the solids expand the least and the gases expand the most.
- One calorie heat is the amount of energy that increases the temperature of 1 g of water by 1^0C. One calorie equals to 4.186 Joule.
- Change of state of a material occurs at some fixed temperatures.
- Melting point is the temperature at which a solid changes to the liquid state.
- Boiling point is the temperature at which a liquid changes to the gaseous state.
- A material melts (goes from solid state to liquid state) at the same temperature as at which it freezes (goes from liquid state to solid state).
- A material condenses (goes from gaseous state to liquid state) at the same temperature as at which it boils (goes from liquid state to gaseous state).
- Some chemical changes need thermal energy while some chemical changes produce thermal energy.
- Bacteria, that spoil edibles, become more active in the normal temperature range (30°C to 45°C).
- The heat required to increase the temperature of an object by 1°C is called its heat capacity.
- The amount of heat required to increase the temperature of one kilogram of a material, by 1°C is called the specific heat capacity of that material. Its unit is joule / kg °C.
- The heat taken or given by an object Q = mst.

Questions for practice

1. Choose the correct answer-

(1) On heating an object, its expansion depends –

(a) On the initial size or the volume of the object.

(b) On the increase in temperature.

(c) On the material used to make the object.

(d) On all the above.

(2) With 10 calorie heat, the temperature of 2 g of water will increase by –

(a) 2°C (b) 5°C (c) 8°C (d) 10°C

(3) The magnitude of heat absorbed by an object depends –

(a) On the mass of the object (b) On the nature of the object

(c) On the increase in temperature (d) On all of them

(4) The heat required to increase the temperature of 1 g of water by 1°C –

(a) 1 calorie (b) 1 kilo calorie

(c) 1 joule (d) 1 kilo joule

(5) Out of the following which unit is not used for measurement of amount of heat–

(a) calorie (b) °C (c) kilo calorie (d) joule

2. Fill in the blanks –

(a) The growth of mammal cells needs a temperature of ……..^{o}C.

(b) Hot water is filled in bottles to massage because it has a high……..

(c) The rate of expansion of mercury is almost the same at all temperatures, therefore it is used in…….

(d) One calorie of heat is equal to ……..joule.

(e) The boiling point of water is …….^{o}C.

3. Give reasons for the following –

(a) When boiling water is poured in to a tumbler made up of thick glass, the tumbler cracks.

(b) In summers to keep the water cool we keep it in pitchers made of red soil and not in metal pitchers.

(c) The mercury in the thermometer rises up on getting hotter.

(d) While sweating contact with air makes us feel cool.

(e) When a gas filled balloon is brought near fire, it bursts.

4. Write two uses of water expansion in daily life.

5. On what factors does the heat required by an object to increase its temperature depend?

6. Calculate the heat required for the following –

(a) To increase the temperature of 0.5 kg water from 25^{o}C to 80^{o}C.

(b) To increase the temperature of 12 kg copper by 50^{o}C.

7. Specific heat capacity of water is 4186 Joule/kg^{0}C and specific heat capacity of glass is 840 Joule/kg^{0}C. If a glass heated at 80^{0}C is kept in water at 80^{0}C. What will be the effect of temperature in both the cases ?

Do these also

1. With the help of a thermometer note the temperature at fixed times daily and write it in the table-

Date	Morning 6:00 A. M.	Noon 12:00	Night 10:00 P. M.