5 WATER

In This Chapter You Will Learn :

- importance of water
- potable water and its need
- water : a compound
- hard water and soft water
- Effect of water scarcity on plants.
- sources of water and water cycle
- purification of water to obtain potable water
- properties of water
- water pollution and control
- Water management

Molecular formula : H_2O, relative molecular mass-18 amu. One molecule of water contains two atoms of hydrogen and one atom of oxygen.

Chemical name: Dihydrogen monoxide.

5.1 IMPORTANCE OF WATER

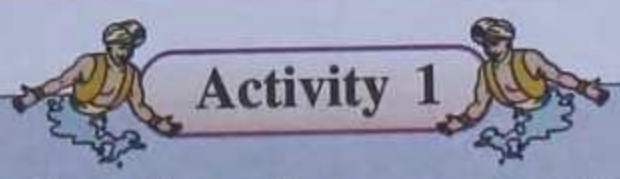
Water is one of the most essential substance for the existence of life. Since life on the earth began in the oceans, and since no living thing can survive without water, it is rightly called the *source of life*.

Water forms a large part of the body mass of all living organisms — 90% of human blood is water. Water has the ability to dissolve a number of substances. Therefore, it serves as the liquid medium in which all reactions within the living body take place.

Fruits and vegetables contain water in them. Even dry-looking substances like wood, peas, beans, grams, *etc*., contain some amount of water.

Table 5.1 : Percentage proportion of water in living things and common eatables

Living things and eatables	*Proportion of water*
Human beings	70%
Elephants	80%
Plants	60%
Leafy vegetables	90%
Potatoes	70%
Tomatoes	95%
Turnips	88%
Water melons	97%
Milk	95%
Eggs	75%
Meat	75%



Activity 1

To show that dry substances contain water.

Take some dry splinters of wood in one test tube, very small pieces of cloth in another test tube, and a few dry bean seeds in the third test tube.

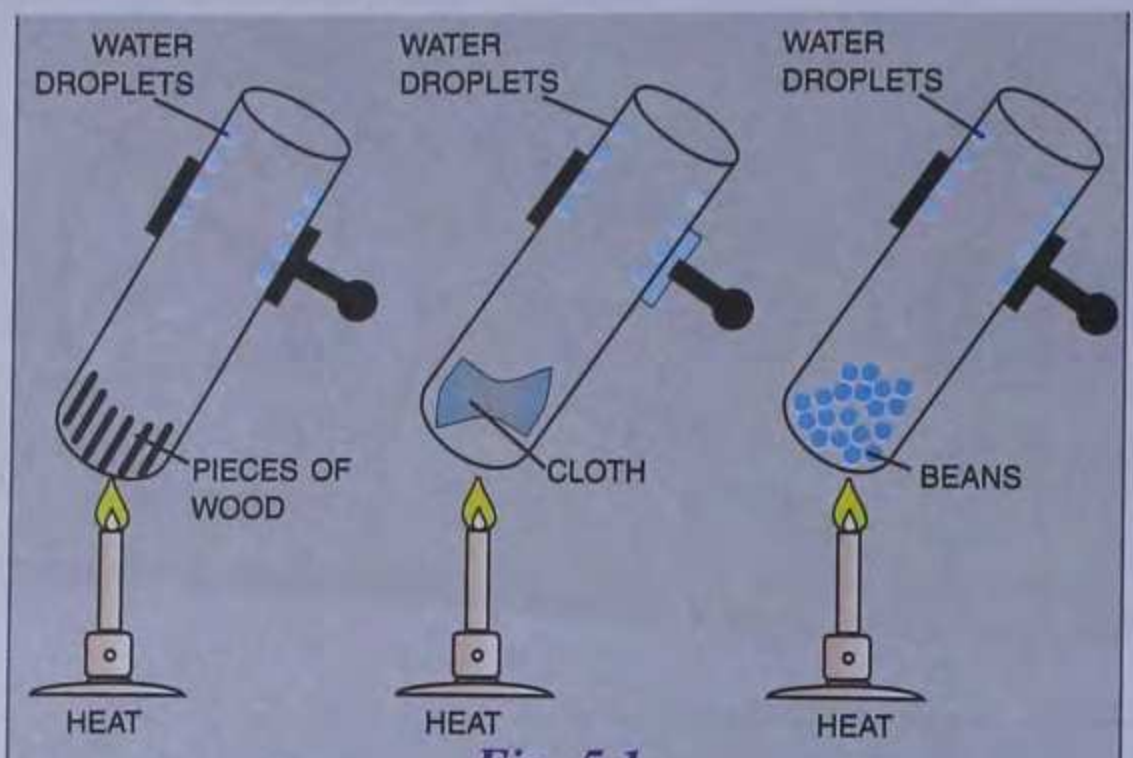


Fig. 5.1

Heat them on a flame. What do you observe ? As the substances start getting charred, we see droplets of water getting deposited on the upper part of the inner walls of the test tubes.

Water is important

1. for everyday uses like cleaning, bathing and washing.
2. for drinking in order to satisfy our biological needs.
3. for growing crops.
4. for various manufacturing processes.
5. for generating electricity.
6. for providing nutrients to aquatic plants and animals.
7. It also helps to control the earth's climate.
8. Water regulates body temperature by the process of sweating and evaporation.
9. Water provides medium for all biochemical reactions inside our bodies to take place.
10. It is essential for the germination of seeds, growth of plants and in photosynthesis.
11. Water inside the bodies of animals/humans dissolves minerals, gases and many products of digestion and carries them at place of need in the body.

5.2 SOURCES OF WATER

Water is widely distributed on the earth. It covers nearly three-fourths of the earth's surface.

Water exists in all the three states of matter, *i.e.*, solid as ice, liquid as water and gas as water vapour.

Under ordinary conditions, water is a liquid, and in this state it is present in oceans, seas, rivers, lakes, ponds, *etc*. It is also present under the ground.

A considerable amount of water is found in the form of ice or snow in very cold regions of the world, *viz*. Arctic, Antarctica, and the high mountains. Frost and hail are the other forms of frozen water.

In the atmosphere, water is present in the form of water vapours, which condenses to form clouds, fog, mist, *etc*.

Activity 2

— Many municipal corporations are trying water-harvesting techniques to improve the availability of water.

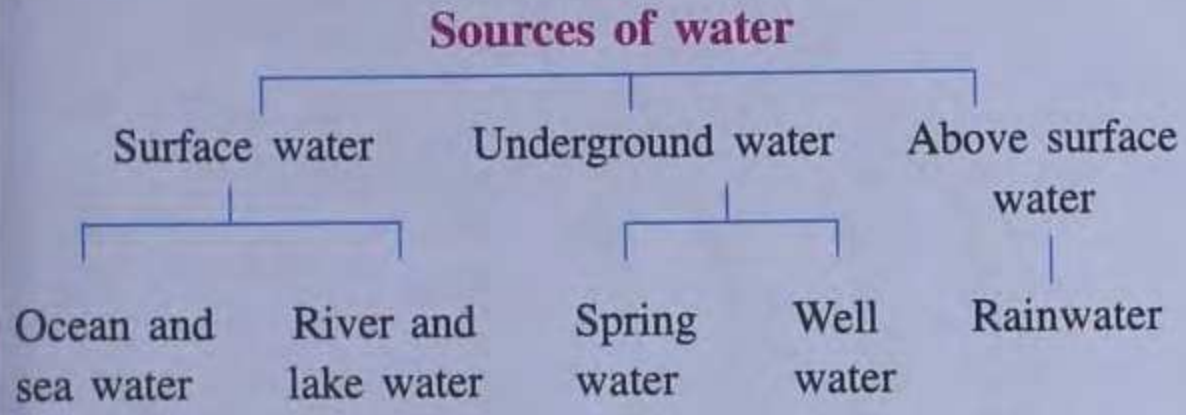
— Find out what these techniques are and how they would increase the water that is available for uses.

Do You Know ?

The electricity produced by using the flow of water from a dam is called hydroelectricity.

Depending on its source and its degree of impurity, natural water is classified into the following types :

1. Ocean and sea water
2. River and lake water
3. Spring and well water
4. Rainwater.



1. Oceans and seas : Oceans and seas are the largest sources of water, covering nearly 71% of the earth's surface. They contain a very high proportion of dissolved substances, mainly common salt. Therefore, ocean and sea water are the most important sources of salt, but they are not fit for direct consumption.

2. Rivers and lakes (These are called surface water sources) : Water in rivers and lakes comes from rain and melting snow. It also contains dissolved impurities like salts, and suspended impurities like clay, sand, twigs and living organisms (germs). Rivers and lakes are the most suitable sources of water for domestic and industrial use. But this water needs to be purified before consumption, since it carries germs that can cause diseases.

3. Springs and wells : These are sources of underground water. This is the water that percolates through the upper layers of the earth's surface and gets collected on the solid rocks beneath. This water is next only to rainwater in its purity. It contains dissolved impurities, but it has no suspended impurities or germs, since it is filtered through the different layers of soil. The taste of spring water differs from place to place. Sometimes this water is rich in minerals, which have medicinal properties.

4. **Rainwater :** It is the purest form of natural water, and it is formed naturally by evaporation followed by condensation of water vapour in the atmosphere. Rainwater dissolves the gases present in the air, and also collects dust particles, as it falls. Some of the important gases dissolved in rainwater are carbon dioxide, oxygen, nitrogen and sulphur dioxide. Rainwater also carries smoke and germs present in the air. Therefore, the first shower of rain contains impurities, but later showers are free from impurities, and therefore safe for drinking.

A major portion of water on the earth is present in the form of snow/ice. Most of the fresh water is frozen in glaciers and polar ice caps.

Activity 3

To show that rainwater does not contain any dissolved impurities but well water contains them.

Take samples of rainwater and well water in two porcelain dishes. Keep the dishes over two beakers containing water. Heat them. As the water in the beakers boil,

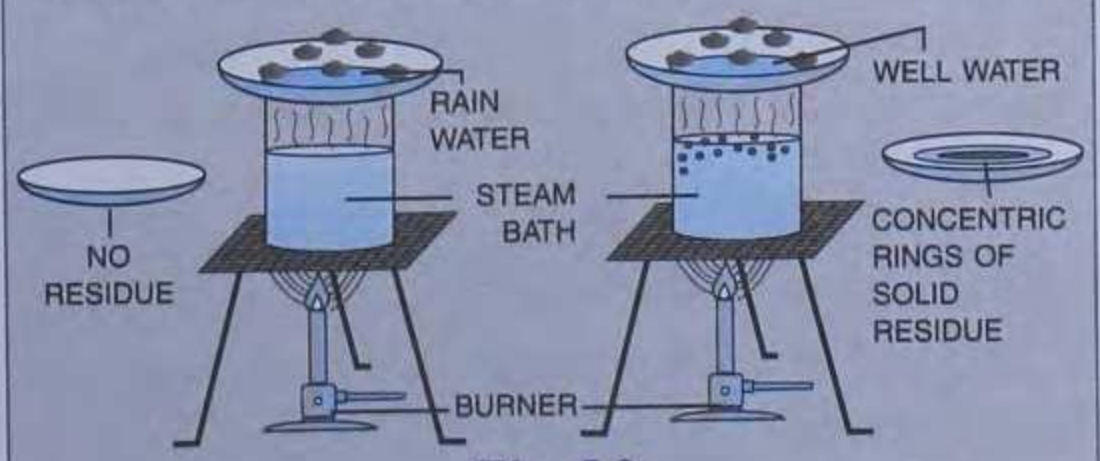


Fig. 5.2

the samples of water in the two dishes evaporate.

What do you observe when both the samples have been completely evaporated ?

The dish containing rainwater has no residue, but the dish containing well water has concentric rings of solid residue. This proves that rainwater is purer than well water.

Do You Know ?

— Seas/oceans contain 97·4% of total water available on the earth.
— The process of removal of dissolved salts from sea/ocean water is called desalination.
— In nature, water exists as snow on high mountains.
— Most of the rivers, lakes, sea and oceans contain water in liquid form.
— Water exists as water vapour in the atmosphere.

5.3 WATER CYCLE

Water is considered a renewable resource on the earth. Water is a substance that is capable of existing in all the three states of matter. From one state it changes into another rather easily.

$$\text{Ice } (s) \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{Water } (l) \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{Water vapour or steam } (g)$$

(0°C or less) (room temperature) (100°C or more)

The change of water from one state to another occurs all the time in nature. *It involves the process of evaporation, condensation and precipitation (rainfall).* This process of *interconversion* helps in balancing the amount of water both in the atmosphere and on the earth's surface, and is known as the **water cycle**.

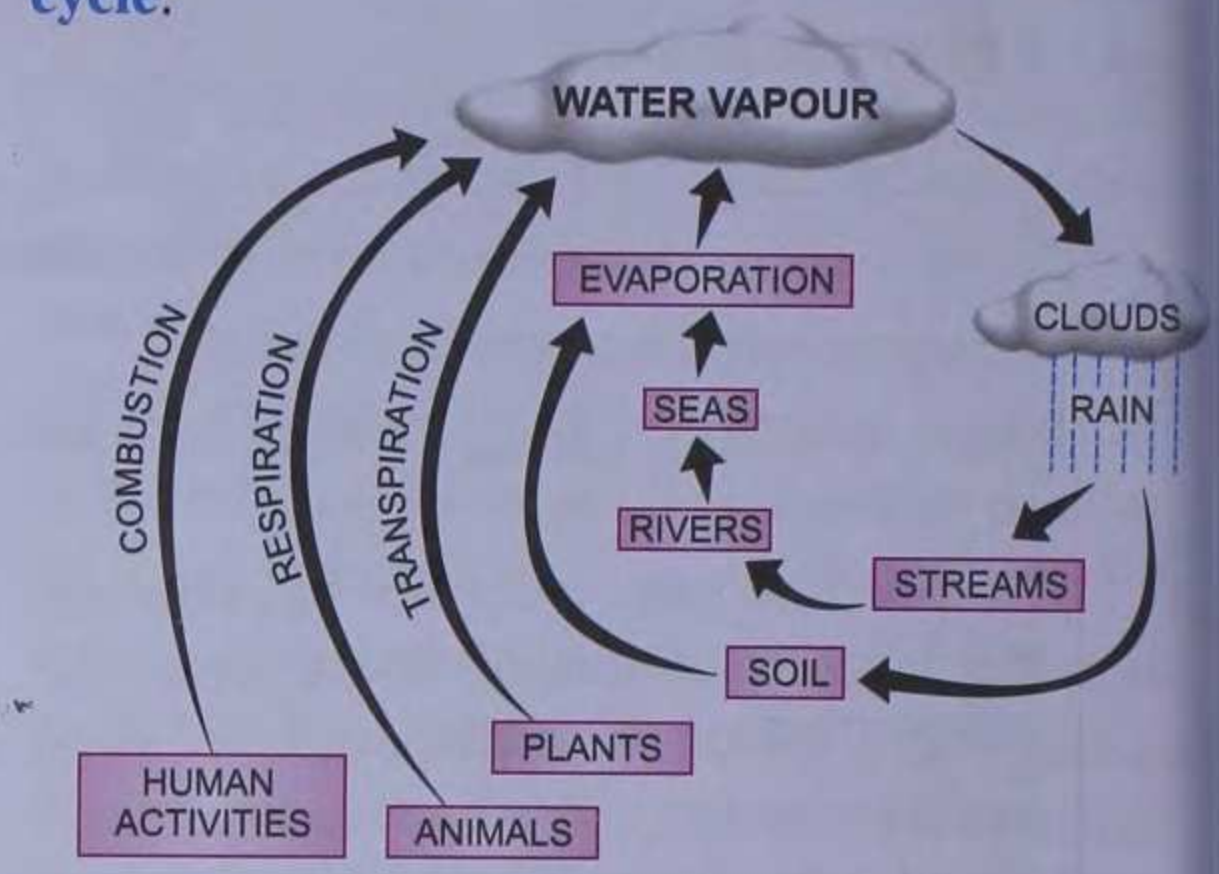


Fig. 5.3 : Water cycle (balances water in nature)

Water is added to the atmosphere by the following natural processes :

1. Evaporation from oceans, seas, rivers, ponds and lakes takes place due to the heat of the sun.
2. Burning of most fuels, mainly fossil fuels.

$$2C_4H_{10} + 13O_2 \xrightarrow{\text{heat}} 8CO_2 + 10H_2O + \text{energy}$$

OR

$$\text{Fuel} + \text{Oxygen} \xrightarrow{\text{heat}} \text{Carbon dioxide} + \text{Water} + \text{Energy}$$

3. Release of water due to respiration by human beings, and animals [$C_6H_{12}O_6$ (glucose) + $6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy].
4. Transpiration by plants.

Water that is released into the atmosphere by these processes rises up in the form of water vapours. These water vapours cool down as they rise, and form clouds in the upper regions of the atmosphere. Clouds contain tiny droplets of water. As they move

up and further cool, these droplets cling to each other and form bigger drops, which fall down as rain. Rainwater gets collected again in seas, rivers, lakes, *etc*. This cycle goes on and on, therefore, it is called the **water cycle**.

When water vapours cool rapidly well below 0°C, they freeze into snow which falls as snow flakes.

Importance of water cycle

1. Water cycle helps in regulating weather on the earth.
2. Water cycle makes water available in various forms on the earth

Do You Know ?

On a humid day air contains a lot of water, thus reducing the rate of evaporation of surface water, from the oceans, seas, rivers, etc. Similarly during rainy season, clothes do not dry quickly.

5.4 WATER AVAILABLE FOR HUMAN CONSUMPTION

Water is necessary for all living beings. We cannot stay alive without water.

The earth's surface contains a very large amount of water. About 71% of the earth's surface is covered with oceans and seas. They constitute about 97% of the earth's total water resources. This water contain a very large amount of salts dissolved in it (approximately 35 g per litre of water). Therefore, sea water cannot be used for human consumption.

The polar ice caps account for 3% of the world's fresh water resources. But water cannot usually be consumed in its frozen state.

Only 1% of all the water on the earth is available in rivers, lakes, springs, *etc*., to support life on land as well as for activities like growing crops and manufacturing goods. Therefore, this water is very precious to us, and so it should be used wisely.

But even this 1% of all water present in rivers, lakes, wells and springs, cannot be used directly, because it contains many impurities.

Impurities Present in Water

Following types of impurities are found in natural water.

1. **Dissolved impurities :** Since water is a very good solvent it dissolves many substances especially mineral salts in it. These are mainly salts of calcium, magnesium, sodium, *etc*. These dissolved impurities cannot be seen through the naked eye. Dissolved impurities can be removed from water by **distillation**.
2. Gases like oxygen, carbon dioxide, *etc*. are also dissolved in natural water.
3. **Suspended impurities :** These are insoluble substances present in water. They can be seen through the naked eye. Suspended impurities are carried by water while it flows down the hills and plains. Common suspended impurities are:
   - clay and sand
   - twigs, straw and leaves
   - decaying organic matter
   - sewage, *etc*.

These impurities are removed by **filtration**.

Germs (Bacteria) : They are very small organisms present in water which can be seen only through a microscope. They are harmful and cause diseases like typhoid, cholera, diarrhoea, gastroenteritis, etc.

Germs can be removed by **sterilization**.

Therefore water needs to be purified before its consumption. This is done by removing impurities and killing germs.

5.5 POTABLE WATER (DRINKING WATER) AND ITS CHARACTERISTICS

Water that is suitable for human consumption is called ***potable water*** *or* ***drinking water****.*

It should have the following characteristics :

1. It should be colourless and odourless.
2. It should be clear and transparent.
3. It should be free from harmful micro-organisms that cause diseases and from other suspended and dissolved impurities.
4. It should contain the minerals* necessary for our body, and also some gases, in order to add taste.
5. It should be free from any harmful salts such as nitrates, cyanides, urea *etc*.

Saline water : Sometimes spring and well water contains a greater amount of salt (2%) than is tolerable for direct use. Such water is called *saline water.* It is unfit for both drinking purposes and irrigation.

* *The minerals are sodium, calcium, magnesium, iron, etc., but an excess of these minerals can be harmful.*

5.6 PURIFICATION OF WATER TO OBTAIN ADEQUATE QUANTITY OF POTABLE WATER

To obtain adequate quantity of potable water for cities and towns, the source of water is usually a lake, or a river running nearby. This water contains both suspended and dissolved impurities. Before supplying it for drinking purposes, this water should be made free from these impurities. Doing this involves the following operations :

Sedimentation : *The settling of suspended solid matter at the bottom of a liquid is called* ***sedimentation****, and the settled solid matter is called* ***sediment****.*

River water is pumped into basins, tanks or reservoirs, and allowed to stand for a few hours. Most of the suspended matter, like sand, clay and silt, settles down. The slower the movement of water, the greater the possibility for the suspended matter to drop to the bottom as *sediment.* But very tiny particles settle down rather slowly. The rate of sedimentation of these minute particles is increased by adding potash alum.

Filtration : *Filtration is the process by which a liquid with insoluble, suspended fine particles is allowed to pass through a filter. The insoluble residue is left behind on the filter, while clear liquid is collected in another container as filtrate.*

For water supply on a large scale, water is filtered through beds of sand, charcoal and gravel. This process removes suspended matter.

Sterilization : *The process of removal of germs is known as sterilization.*

The filtered water may still contain germs or bacteria which may cause water-borne

diseases. Therefore they need to be removed. Some of the methods to remove germs are :

(i) ***By exposure to air and sunlight :*** Air containing oxygen and sunlight, both have the effect of burning the germs to death. When water in reservoirs is exposed to air and sunlight over a large surface area, the germs are killed to some extent, but not completely because the rays of the sun cannot reach the lower layers of the water.

(ii) ***By chemical treatment :*** Chemicals like chlorine and ozone kill bacteria and other germs present in water. Chlorine is sometimes replaced by bleaching powder, for this purpose, which slowly reacts with water to give chlorine and kills the germs. Treatment with ozone is called *ozonization*. Swimming pools too are chlorinated to protect swimmers from the danger of infection.

Aeration : *Air under pressure is blown into the filtered water. This process is called aeration, kills harmful micro-organisms present in the filtered water.*

Prolonged boiling is one more important method of killing bacterias, but this method can be applied over a small scale only.

Water after the removal of suspended impurities and germs is collected in overhead tanks and then supplied for domestic use through pipes. Therefore the potable water so obtained is also called **"tap water"**.

Tap water still contains dissolved impurities which are mainly minerals and salts necessary for our body. But excess of these may not be good for health.

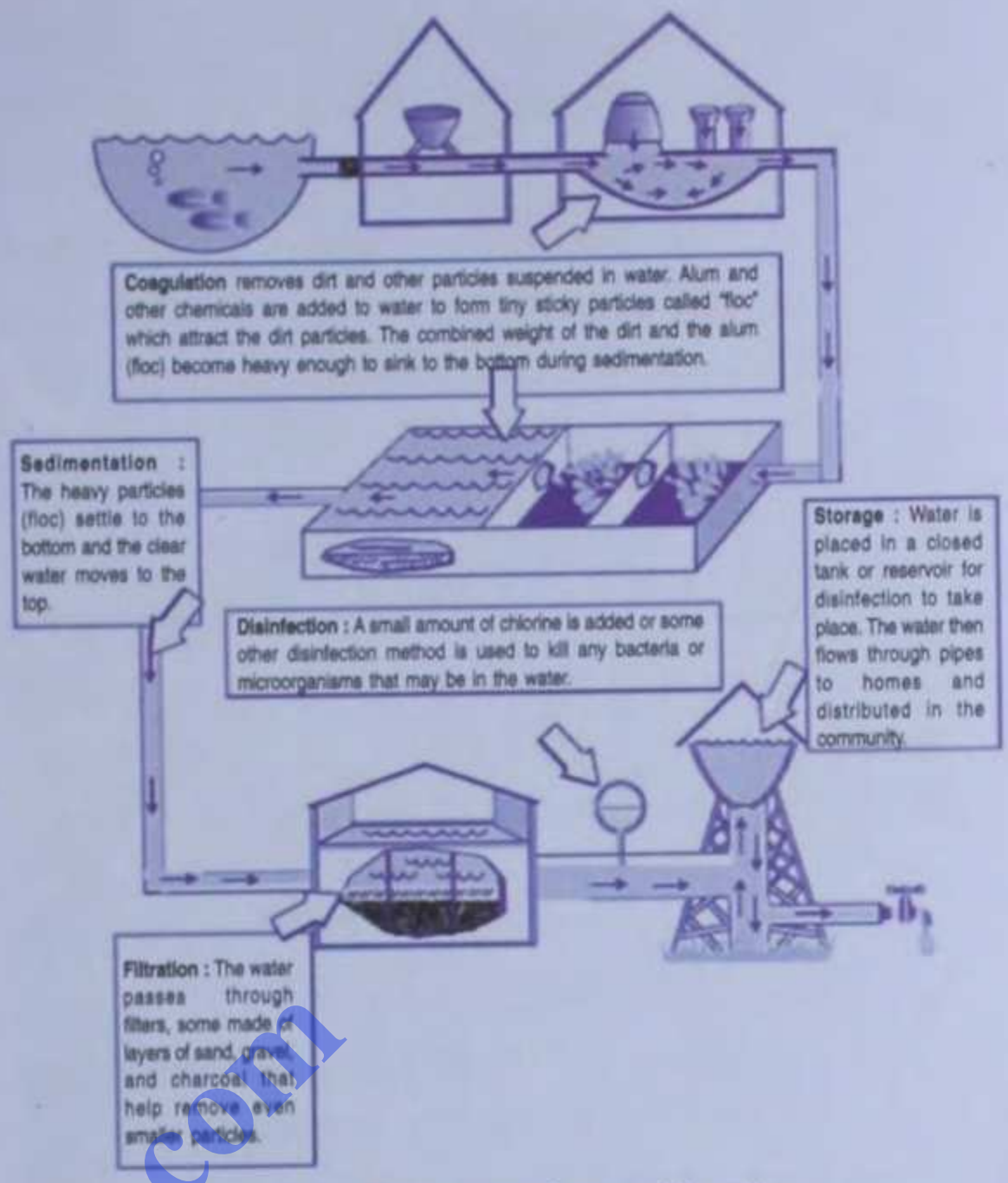


Fig. 5.4 : Large-scale purification of water for drinking.

There are other household methods also to get drinking water :

(i) By boiling water

(ii) By water purifiers which are now made available by different companies.

Water purifers

Do You Know ?

R.O. and UV water purifiers are better than ordinary filters used in home because they not only filter the suspended particles but also filter or kill the germs.

(iii) By adding calculated amount of chlorine to the water stored in tanks on the roofs of houses to kill the germs.

(iv) By filtration — Any suspended impurities in water from well, river, or lake can be removed by filtering water through a fine muslin cloth

Do You Know ?

Sea water is not fit for drinking, cooking and washing because it contains high concentration of salts. It induces vomiting.

5.7 PURIFICATION OF WATER BY DISTILLATION

Distillation : The process of converting a liquid into vapour by heating and the subsequent condensation of the vapour, back into a liquid is called **"distillation"**.

This method is used to remove dissolved impurities from water. The water obtained after distillation is called **distilled water**. It is the purest form of water.

Impure water is kept in the distillation flask and boiled water turns into steam and

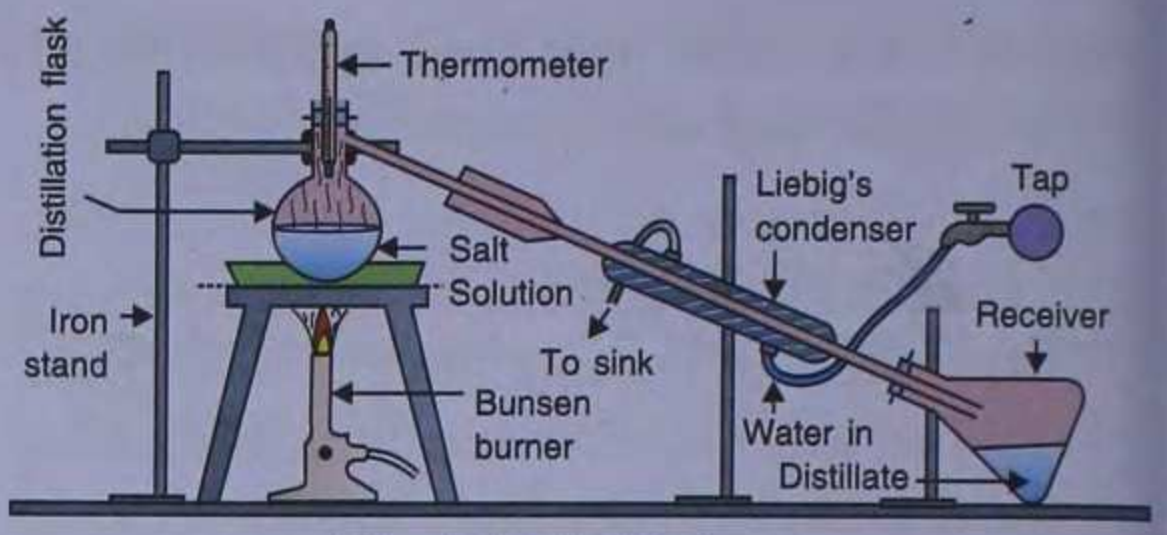


Fig. 5.5 Distillation

passes through the Liebig condenser. Steam again changes into liquid water through cold contact and gets collected as distillate (distilled water) in the receiver.

The dissolved impurities remain in the flask. Therefore, by this process both the dissolved solids and pure water are recovered.

Distilled water is used

(i) for preparing solutions for medicinal purposes.
(ii) for experiments in the laboratory.
(iii) for car batteries.

But it cannot be used for drinking purposes because it does not contain any salt and minerals which are necessary for the proper growth of our bodies. Also it does not contain any gas due to which it is flat to taste.

EXERCISE – I

1. Name the four main sources of natural water.
2. How is water added to the atmosphere ? How does this water come back on the earth ? What is the process known as ?
3. What is potable water ? Give three main characteristics of potable water.
4. What are the three main types of impurities present in water ? How can they be removed from it ?
5. How is water purified on large scale to make it potable? Explain all the steps.
6. List three household methods to get drinking water.
7. What is distilled water ? What are its uses?
8. Give reason :
   (a) Distilled water is flat to taste.
   (b) Distilled water is not suitable for drinking.

5.8 WATER : A COMPOUND

Water has been used by man ever since he came into existence. Owing to its high stability, water was initially considered to be an element. Henry Cavendish, in 1781, proved that water is a compound made up of two elements : hydrogen and oxygen. He obtained water by burning hydrogen in air with the help of an electric spark. *The conclusion made by Cavendish (about water) was later supported by Lavoisier.*

Water breaks up into its constituent elements, *viz.* : oxygen and hydrogen when heated to a temperature of 2000°–3500°C or when an electric current is passed through it. But for this process to take place, water must contain a small amount of salt or acid in it. This process is called electrolysis.

The process of breaking down of a compound, which is in a molten or a solution form, by passing an electric current through it, is called electrolysis.

Activity 4

To demonstrate the electrolysis of water.

Take an apparatus called Hoffman's voltmeter. Fill it with acidified water, and invert two test tubes filled with water over the carbon electrodes of the apparatus, so that they are dipped in water. Connect the electrolytic cells to a battery with the help of a wire.

Now pass an electric current through the water. You will observe that, in both the tubes, gases are collected, but the volume of gas collected in tube B, inverted over the negative electrode, is double that of the volume of gas collected in tube A, inverted over the positive electrode. Keep passing current until the test tube at the negative electrode (cathode) is completely full of gas. Then stop passing current and take out the test tubes for testing the gas.

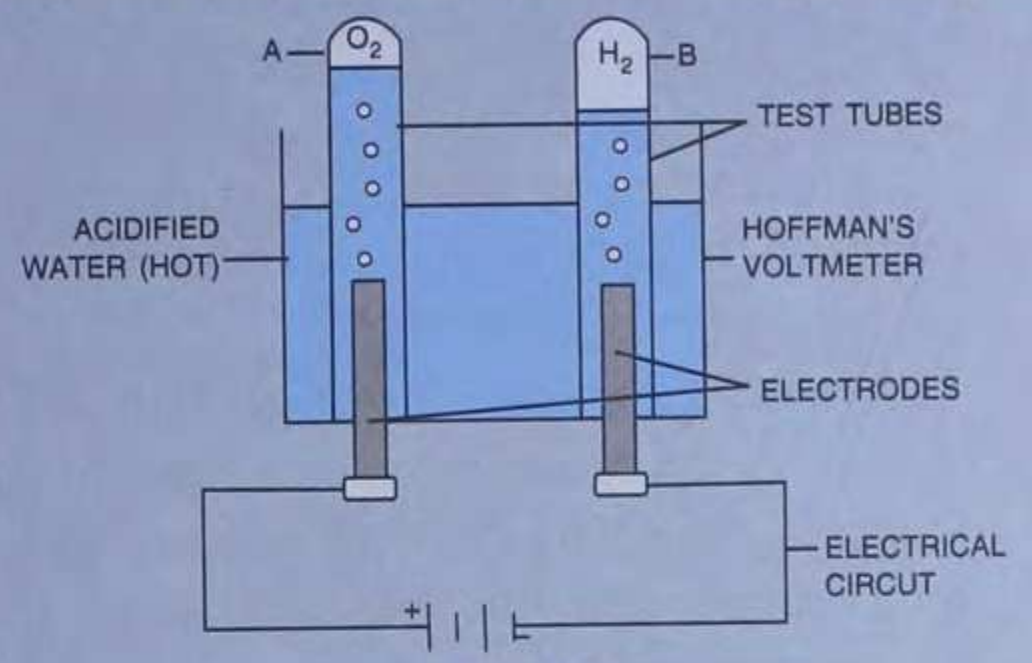


Fig. 5.6

When a burning splinter is brought near test tube B, the gas burns with a pop sound, indicating that the gas is *hydrogen*.

But when a glowing splinter is brought near the mouth of test tube A (inverted over the positive electrode), the splinter bursts into a flame, indicating that the gas is *oxygen*.

Thus, from the above experiment, it is clear that water is formed by the combination of two elements, hydrogen and oxygen, in a definite proportion of 2 : 1 by volume.

From whichever source water is taken, it has the same chemical composition. One molecule of water is represented by the formula H_2O. The chemical name is *Dihydrogen monoxide*.

$$2H_2O \xrightarrow[\text{current}]{\text{electric}} 2H_2 + O_2$$

Cathode is the negative electrode whereas ***anode*** is the positive electrode in an electrolytic cell.

For ***electrolysis*** of water, acid or salt is added to it, because pure water is a bad conductor of electricity. Hydrogen is obtained at the cathode and oxygen is obtained at the anode.

5.9 PHYSICAL PROPERTIES OF WATER

1. Pure water is a colourless, transparent liquid at room temperature. It is tasteless and odourless, too. The water we drink has taste because it contains dissolved substances.
2. **The freezing point** of pure water is 0°C. This is the temperature at which water starts changing into ice. The temperature remains constant at the freezing point till all the water has frozen.
3. **The melting point** of ice is also 0°C, which is the temperature at which ice starts changing into water. The temperature remains constant till all the ice has melted.
4. **The boiling point** of water is 100°C. Under normal pressure it is the temperature at which pure water boils and starts changing into steam. The temperature remains constant till all the water has boiled and changed into steam.

The effect of pressure on the boiling and freezing points of water

The boiling point of water decreases with a decrease in pressure, and increases with an increase in pressure. Therefore, water boils at a lower temperature in the hills, where the atmospheric pressure is lower than in the plains. That is why it takes a longer time to cook in hilly regions.

Do You Know ?

Food is cooked in less time in a pressure cooker because the pressure increases inside the cooker, which also increases the boiling point of water. More heat is required to reach the boiling point, which is sufficient to cook food in reduced time.

The pressure under a skater's shoes melts the ice, which freezes again when the skater moves on. This results in melting of snow because of an increase in pressure, and the skater glides on water.

The effect of impurities present in water

Any impurity present in water lowers its freezing point and raises its boiling point.

For example, salt is added to ice to lower its melting point. Such a mixture is called a *freezing-mixture*. The melting point of the freezing mixture is about –15°C.

Similarly, alcohol is added to the water used in car radiators to prevent it from freezing in cold weather.

Why doesn't sea water freeze so easily ?

5.10 SPECIFIC HEAT OF WATER

Water has high specific heat*. This means that water needs a large amount of heat to become hot, and it needs to lose a large amount of heat to become cold. In other words, water neither heats up nor cools down quickly.

This property makes water an excellent cooling agent. Water is used as a cooling agent in car engines, factories, nuclear reactors, *etc*. It absorbs the heat produced in an engine or a machine or some other part of a factory, and prevents it from becoming too hot.

Water also acts as a natural cooling agent. Land breeze and sea breeze occur due to this property of the high specific heat of water.

Sea breeze and ***Land breeze*** take place in the coastal regions due tó which those

* The specific heat of a substance is the amount of heat required to raise the temperature of a unit mass of that substance by one degree centigrade.

regions have moderate climate, *i.e.*, neither too hot nor too cold.

Sea breeze : The flow of cold air from sea to land during daytime is called *sea breeze*. As water has high specific heat, the land becomes hot earlier than sea water during day time. The hot air above the land rises up and the cold air above sea water flows towards the land. Thus the days are not very hot in those areas.

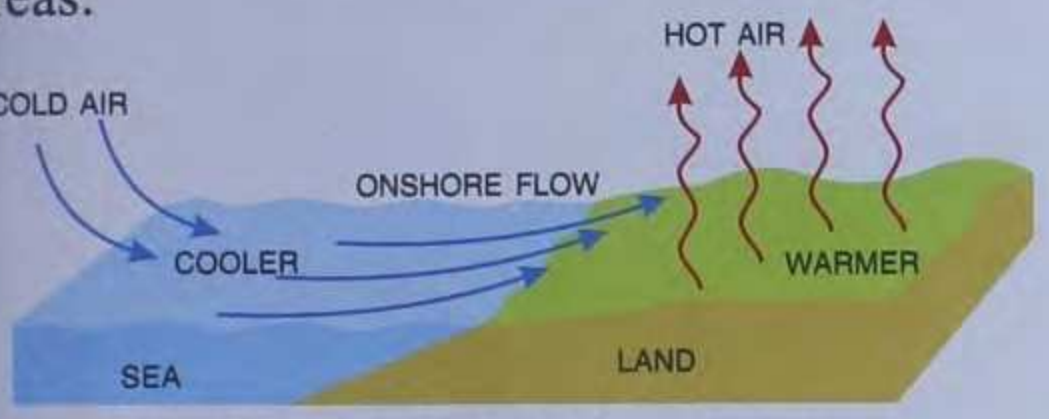


Fig. 5.7 : Sea breeze (during daytime)

Land breeze : The flow of air from land to sea at night is called land breeze. At night the land becomes cold sooner than sea water. As a result, the hot air above sea rises up and the cold air from land moves towards the sea. Thus, the nights are not very cold in coastal areas.

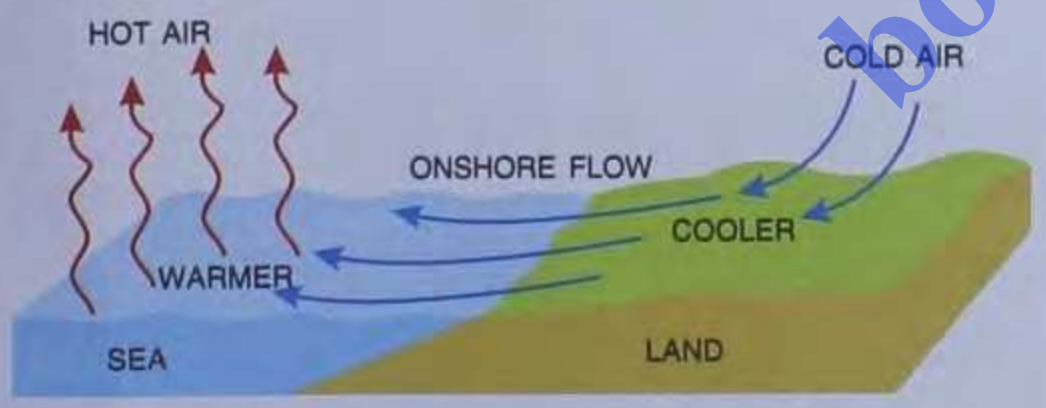


Fig. 5.8 : Land breeze (at night)

Why is water used in room coolers and hot water bags ?

Do You Know ?

At 0°C water can exist in all its three states : solid, liquid and gas. Therefore, 0°C is called the **triple point** of water.

5.11 ANOMALOUS EXPANSION OF WATER [RELATIVE VOLUME AND DENSITY OF ICE AND WATER]

The density of a substance is its mass per unit volume, while volume is the space occupied by the mass of the substance. Usually, the solid form of a given substance has greater density, and it is also heavier than the liquid form (for the same volume).

In the case of water, its solid form (ice) is lighter than its liquid form. **This is an anomalous phenomenon** also called as anomalous expansion of water.

Generally, when something is heated, it expands and its density decreases, and when it is cooled, it contracts and its density increases. Accordingly, when water is cooled, it contracts and its density increases, but only until the temperature reaches 4°C, because on further cooling, water starts expanding, with a decrease in its density, which is an anomalous phenomenon. At 0°C, it becomes ice, and this ice floats on water. *The density of water is, therefore, the greatest at 4°C, which is equal to 1 gm/cm^3 or 1 kg/litre.*

Freezing lakes : The anomalous expansion of water is a great boon to aquatic life in cold regions. When the temperature falls, the water on the surface of lakes initially cools and contracts. The heavier, colder water sinks, and the surface water again cools. This process continues till the temperature reaches 4°C. On further decrease in temperature, the surface water expands and becomes lighter. Now it does not sink. Therefore, further cooling takes place only at the surface, while the temperature of the lower layers of water does not change. Eventually, the water at the

surface changes into ice, which floats over the water below. Ice is a poor conductor of heat and acts like a blanket that protects the bottom layers of the water from the cold air above. This is how fish and other living organisms live inside lakes during winter, even though there is ice at the surface. As the temperature dips further, the thickness of the surface of ice increases.

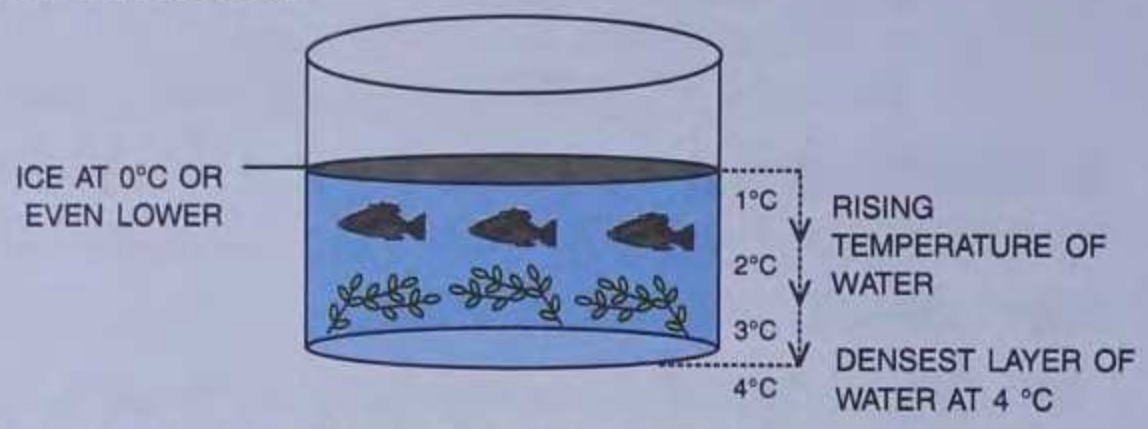


Fig. 5.9 : The topmost layer cools and ultimately freezes, while the bottom layers remain at 4 °C

In the colder parts of the world, water pipes burst when the water inside them freezes in winter. Why ?

5.12 WATER — AN EXCELLENT SOLVENT

A liquid, which dissolves another substance to form a solution, is called a *solvent*. The substance that dissolves in the solvent is called the *solute*, while a *solution* is the homogeneous mixture of solute and solvent.

Solution = Solvent + Solute

Water is often termed the *universal solvent*, because it dissolves almost all kinds of solid, liquid and gaseous substances. Where the amount of the solute may be more or less.

Water can even dissolve the minute particles of the container in which it is kept. It even corrodes our internal body parts if drunk in its purest form (*distilled water*).

The capacity of water to dissolve substances, and its importance as a solvent, can be explained by the following activity.

Activity 5

Take some water in a glass. Add some sugar to it and stir properly. You will observe that all the sugar disappears. It means that sugar has been dissolved in the water. Add some more sugar to it. Again it dissolves. Go on adding sugar to the solution formed in the glass, till no more sugar dissolves in it.

This solution is said to be *saturated*, while the solution that can keep dissolving more solute at a particular temperature, is said to be *unsaturated*.

Now, heat the solution. You will observe that the sugar that was not dissolved earlier, now gets dissolved.

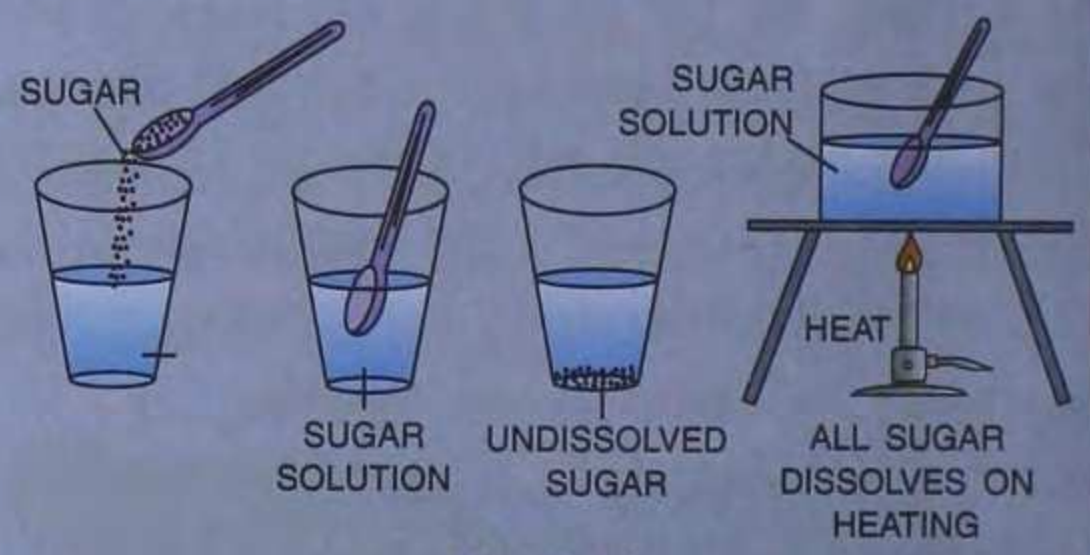


Fig. 5.10

This solution is said to be *supersaturated*.

This shows that water has a great capacity to dissolve substances. It also shows that an increase in temperature increases the dissolving capacity of water.

Conclusion : Water can dissolve a substance but only upto a limit.

- Solid substances like salt, sugar, baking soda, washing soda, *etc.*, readily dissolve in water.

- Liquids like fruit juice, alcohol, vinegar, *etc.*, also dissolve in water. Such liquids are called **miscible** liquids.

*The liquids which do not dissolve in water are called **immiscible** liquids. E.g. petrol, diesel, mustard oil, etc.*

- Many gases like oxygen, carbon dioxide and ammonia also dissolve in water.

Do You Know ?

Solution of any substance in water is called its aqueous solution.

No chemical reaction takes place when a substance (solute) is dissolved in a solvent to prepare its solution.

Effect of temperature on solubility of a substance (solute) in water

- Solubility of a solid solute generally increases with an increase in temperature. This makes it possible to prepare supersaturated solutions.
- Solubility of a gas decreases with an increase in temperature. That is why gases dissolved in water can be easily expelled by boiling. Boiled water has a flat taste.

Do You Know ?

Often during summer, fish in shallow ponds die. This is because the water in the pond gets warm due to summer heat, as a result, the amount of dissolved oxygen in water decreases and the fish in that pond die.

Effect of pressure on the solubility of a substance (solute) in water

- Pressure has practically no effect on the solubility of a solid (solute) in water.
- In the case of gases, the amount of a gas dissolved in water increases with an increase in pressure and decreases with a decrease in pressure. That is why carbonated drinks (cold drinks, soda *etc.*) which contain carbon dioxide are bottled under high pressure, *i.e.*, they contain a large amount of gas in them.

When we open a bottle of a carbonated drink, some of the gas comes out with a hissing sound. Why ?

5.13 THE IMPORTANCE OF THE GASES AND MINERALS DISSOLVED IN NATURAL WATER

1. Natural water contains dissolved gases like oxygen, nitrogen and carbon dioxide.
   - Oxygen dissolved in water is the main source of survival for marine life.
   - Carbon dioxide dissolved in water is used by plants for photosynthesis.
   - Nitrogen in water converts into nitrogenous compounds by the action of bacteria and serves as a mode of nourishment for water plants.
2. Some of the salts dissolved in natural water are essential for the proper growth of our bodies. They also add taste to drinking water.
3. Sea water contains a large amount of common salt(sodium chloride) dissolved in it.

Evaporation of sea water gives solid *common salt,* which is an essential ingredient of our food. It is added to our food for taste and for the proper growth and development of our bodies.

Chemical properties of water

1. Pure water is neutral to litmus which means that no change in the colour of blue or red litmus solution is observed when treated with water.
2. *Action of heat or electrolysis :* Water is a highly stable compound. However, when heated above 2000°C or when electric current passes through water, it decomposes into hydrogen and oxygen gases.

$$2H_2O \xrightarrow[\text{or electrolysis}]{2000°C} 2H_2 + O_2$$

3. *Action of water on elements :*

A. **On metals :** Water reacts with active metals like sodium, potassium, magnesium, calcium, iron, *etc.*, under different conditions to produce hydrogen gas.

Sodium + Water (cold) $\xrightarrow{\text{fast}}$ Sodium + Hydrogen hydroxide

$$2Na + 2H_2O \text{ (cold)} \longrightarrow 2NaOH + H_2(g)$$

Calcium + Water (cold) $\xrightarrow{\text{slow}}$ Calcium + Hydrogen hydroxide

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2(g)$$

Magnesium + Steam $\longrightarrow$ Magnesium + Hydrogen oxide

$$Mg + H_2O \text{ (steam)} \longrightarrow MgO + H_2(g)$$

B. **On non-metals :**

(i) Non-metals like carbon (coke) reacts with steam to produce water gas, which is an important industrial fuel.

Coke + Steam $\xrightarrow{1000°C}$ Water gas.

$$C + H_2O \xrightarrow{1000°C} [CO + H_2]$$

(red hot) Water gas

(ii) Chlorine gas dissolves in water to produce chlorine water, which contains hydrochloric acid and releases oxygen gas on exposure to light.

$$Cl_2 + 2H_2O \xrightarrow{\text{sunlight}} 2HCl + O_2$$

Activity 6

To find out if the given substance is soluble or insoluble in water.

Materials required : A few substances like common salt, sugar, starch, sulphur, alcohol and test-tubes.

Procedure : Take about 5 mL water in each of the five test-tubes and place them on a test-tube stand. Add a pinch of common salt in test-tube 1, of sugar in test-tube 2, of starch in test-tube 3, of sulphur in test-tube 4 and about 1 mL of alcohol in test-tube 5. Shake each test-tube for a while and put the test-tube back to the test-tube stand. Note, if the substance dissolves in water or not. From the experiment you will observe the following results :

Test-tube	Substance	Soluble or insoluble
1.	Common salt	Soluble
2.	Sugar	Soluble
3.	Starch	Insoluble
4.	Sulphur	Insoluble
5.	Alcohol	Soluble or miscible

Conclusion : Common salt, sugar and alcohol are soluble in water, whereas starch and sulphur are insoluble in water.

4. *Action of water on compounds :*

A. **On metallic oxides :** Water dissolves metallic oxides like sodium oxide, potassium oxide, *etc*., to produce metallic hydroxides also known as alkalis.

Sodium oxide + Water $\longrightarrow$ Sodium hydroxide (alkali)

$$Na_2O + H_2O \longrightarrow 2NaOH$$

Potassium oxide + Water $\longrightarrow$ Potassium hydroxide (alkali)

$$K_2O + H_2O \longrightarrow 2KOH$$

Calcium oxide + Water $\longrightarrow$ Calcium hydroxide (alkali)

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

B. **On non-metallic oxides :** Oxides like carbon dioxide, sulphur dioxide, nitrogen dioxide, *etc*., dissolve in water to produce acidic solutions.

Carbon dioxide + H_2O $\longrightarrow$ Carbonic acid

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

Sulphur dioxide + Water $\longrightarrow$ Sulphurous acid

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

Test for Water

1. Water can be tested by its boiling point (100°C) and freezing point (0°C) if it is pure.
2. When a few drops of water are added to anhydrous copper sulphate powder, its colour changes from **white to blue**.

Fig. 5.11: Adding water to white copper sulphate turns them blue

3. When a few drops of water are added to **blue** cobalt chloride its colour changes into **pink**.

EXERCISE – II

1. Define the following terms :
   (a) Melting point (b) Boiling point
   (c) Specific heat (d) Solvent
   (e) Electrolysis (f) Sterilization
   (g) Solubility
2. Name the two gases from which water is formed. What is the chemical composition of these two gases in water ? Give the molecular formula of water.
3. Name the products formed when water reacts with
   (a) sodium (b) calcium
   (c) calcium oxide (d) carbon dioxide
4. Give reasons :
   (a) Water is used as a cooling agent.
   (b) Distilled water should not be used for drinking.
   (c) Water pipes burst in severe winters.
   (d) It is difficult to cook in hills as compared to plains.
   (e) Ice floats on water.
   (f) Sea water does not freeze at 0°C.
   (g) Small amount of acid is added to water before electrolysis.
5. How does anomalous expansion of water help aquatic organisms in cold climates ?
6. Give balanced chemical equations for the following:
   (a) Magnesium + water → magnesium oxide + hydrogen
   (b) Carbon dioxide + water → carbonic acid
7. Give *two* examples for each of the following :
   (a) Miscible liquids (b) Immiscible liquids

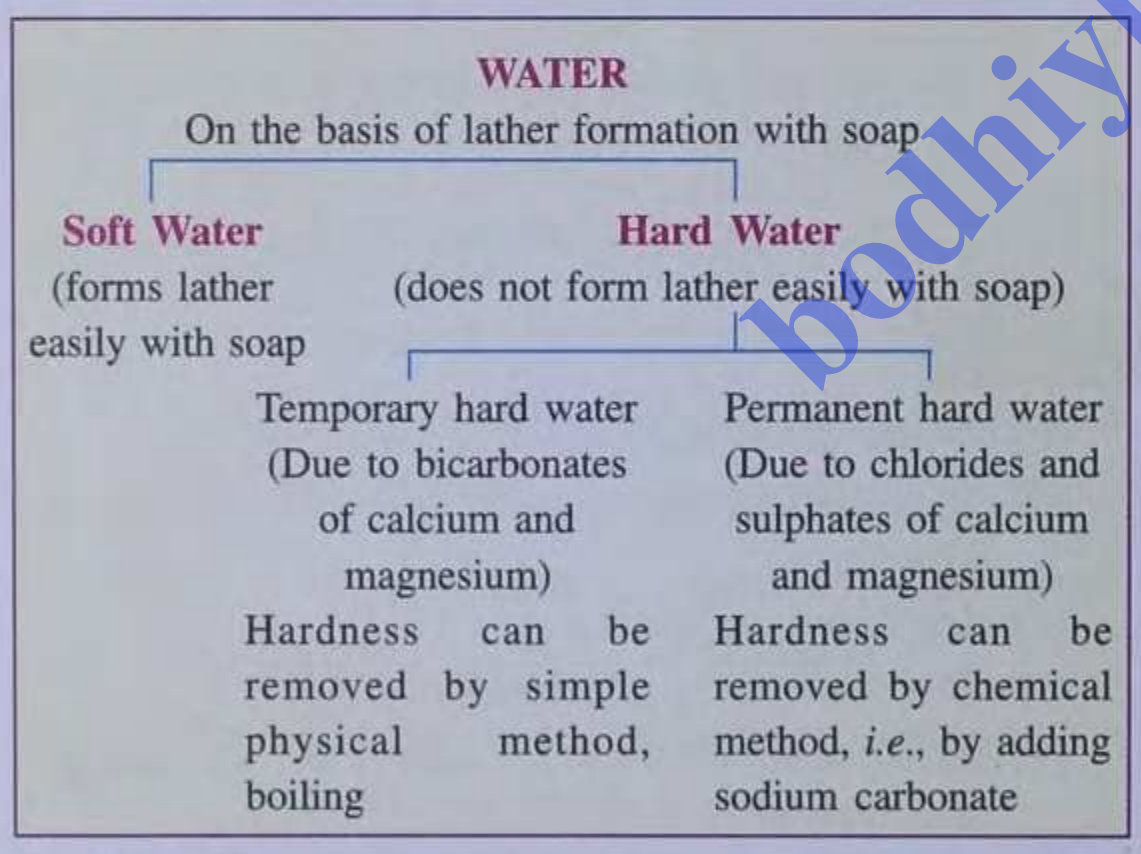
5.14 HARD WATER AND SOFT WATER

The water present in different natural sources has different substances dissolved in it. It has been found that water drawn from certain sources forms a lather with soap rather easily. Such water is called *soft water.*

Whereas, water obtained from some other sources does not easily form a lather with soap, rather it forms a white sticky scum or a precipitate. This water is called hard water.

Hard water is of two types :

(i) ***Temporary hard water :*** Water, which has bicarbonates of calcium and magnesium dissolved in it, is temporary hard water. This kind of hardness can be easily removed by boiling.



(ii) ***Permanent hard water :*** Water, which has sulphates and chlorides of calcium and magnesium dissolved in it, is called permanent hard water. This hardness cannot be removed by boiling.

Differences between hard water and soft water

Hard water	Soft water
1. Hard water does not easily form lather with soap.	1. Soft water easily forms lather with soap.
2. It is not good for drinking or making solutions or washing clothes.	2. It is good for drinking or preparing solutions or washing clothes.

5.15 DISADVANTAGES OF HARD WATER

1. Hard water is not safe for drinking.
2. It results in wastage of soap.
3. It leaves a substance at the bottom of the container when it is boiled. This substance is called scale (or fur) which damages the container.
4. Hard water is not suitable for preparing solutions.

5.16 CAUSES OF HARDNESS OF WATER

Temporary hard water is formed when rainwater containing carbon dioxide flows over rocks made of calcium or magnesium carbonate. This results in the formation of their bicarbonates, which dissolve in water, making it temporarily hard.

5.17 REMOVAL OF HARDNESS OF WATER

The hardness of water is to be removed to make it consumable in homes, laundries, factories, *etc*. When dissolved salts of calcium and magnesium are removed from water, it becomes soft. The following are some of the methods used to remove the hardness of water.

1. **Boiling :** This method helps to remove only the temporary hardness of water. When temporary hard water is boiled, the

bicarbonates of calcium and magnesium break up to form their respective insoluble carbonates. These can be filtered out so that water becomes soft.

$$\underset{\text{(soluble calcium bicarboate)}}{Ca(HCO_3)_2} \xrightarrow{\text{boiled}} \underset{\text{(ppt) (calcium carbonate)}}{CaCO_3} + \underset{\text{(water)}}{H_2O} + \underset{\text{(carbon dioxide)}}{CO_2(g)}$$

$$\underset{\text{(soluble magnesium bicarboate)}}{Mg(HCO_3)_2} \xrightarrow{\text{boiled}} \underset{\text{(ppt) (magnesium carbonate)}}{MgCO_3} + \underset{\text{(water)}}{H_2O} + \underset{\text{(carbon dioxide)}}{CO_2(g)}$$

2. **By adding sodium carbonate :** The permanent hardness of water is removed when such water is treated with a small quantity of sodium carbonate. It reacts with the soluble chlorides and sulphates of calcium and magnesium to form their respective insoluble carbonates. These can be removed by filtration and then the water becomes soft. Sodium sulphate or sodium chloride formed after the reaction does not affect the soap.

$$\underset{\text{(sodium carbonate)}}{Na_2CO_3} + \underset{\text{(calcium sulphate)}}{CaSO_4} \longrightarrow \underset{\text{(insoluble calcium carbonate)}}{CaCO_3} + \underset{\text{(soluble sodium sulphate)}}{Na_2SO_4}$$

$$\underset{\text{(sodium carbonate)}}{Na_2CO_3} + \underset{\text{(magnesium chloride)}}{MgCl_2} \longrightarrow \underset{\text{(insoluble magnesium carbonate)}}{MgCO_3} + \underset{\text{(soluble sodium chloride)}}{2NaCl}$$

Activity 7

Take some tap water in beaker A. Add a pinch of magnesium chloride to it and stir so that it gets dissolved. Now the tap water has become hard. Pour half of that water in another beaker B.

(i) Add some soap solution in beaker A and stir.

(ii) Add some washing soda ($Na_2CO_3 \cdot 10H_2O$) in beaker B and stir. A white insoluble solid ($CaCO_3$) is formed. Allow it to settle and then filter it. Now add some soap solution to this water and stir.

What are your observations ?

You observe that in beaker A no lather has formed but in beaker B, lather is formed.

This is because beaker A contains hard water but the water in beaker B becomes soft on adding washing soda.

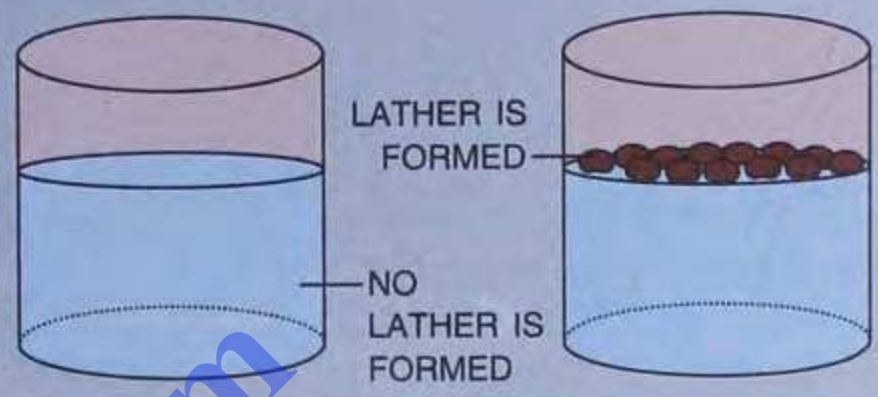


Fig. 5.12

Do You Know ?

Detergents act on the same way as soap but they do not form scum with hard water.

5.18 WATER POLLUTION

Water pollution is the contamination of water which makes it unfit for many type of uses, *i.e.*, undesirable changes in the physical chemical and biological conditions of water that make it unfit for human consumption, is called water pollution.

The pollution of fresh water is one of the most serious environmental problem faced by the world today. The water present in rivers, ponds, lakes and streams, comes from rain and the melted snow of the mountains. As it flows down the plains, it picks up many dissolved and suspended impurities. This water further

increases in its impurity by the addition of the waste products from homes, agricultural lands and industries. These waste products are very harmful. They are called **pollutants,** because they make the water impure and polluted.

5.19 CAUSES OF WATER POLLUTION

1. **Industrial and agricultural processes :** Water is required in large quantities in industries and in agriculture for different purposes. But care is not taken to keep the water fit for consumption. Most of the industries dump their wastes in rivers and even into the sea.

   Fertilizers, pesticides, insecticides and other chemicals used in cultivated fields, get dissolved in water when it flows across these fields. This adds undesirable chemicals into the water. Acidic water from mines and acid rain also pollute the water in rivers and seas. These chemicals are dangerous for aquatic life, and they make the water unfit for consumption.

2. **Nuclear and thermal power plants :** Power plants use large amounts of water for cooling purposes. They discharge the resultant hot water, often containing chemicals, into water streams. This results in an increase in the temperature of water, which is injurious for fish and other aquatic life forms.

   - Contamination of rivers, lakes, *etc.*, with heavy metals like lead, mercury, copper, nickel, *etc*. can harm both aquatic and human beings.

Fig. 5.14

3. **Sewage and garbage :** The discharge of sewage and garbage into river water is another major cause of water pollution. Water becomes unsafe for drinking and other uses due to people urinating, defecating or washing in it. Different kinds of germs grow that causes diseases in polluted water.

   Almost two-thirds of all the illnesses in India are water-borne, such as typhoid, hepatitis, cholera, diarrhoea, dysentery, *etc*.

PICTURES SHOWING WATER POLLUTION

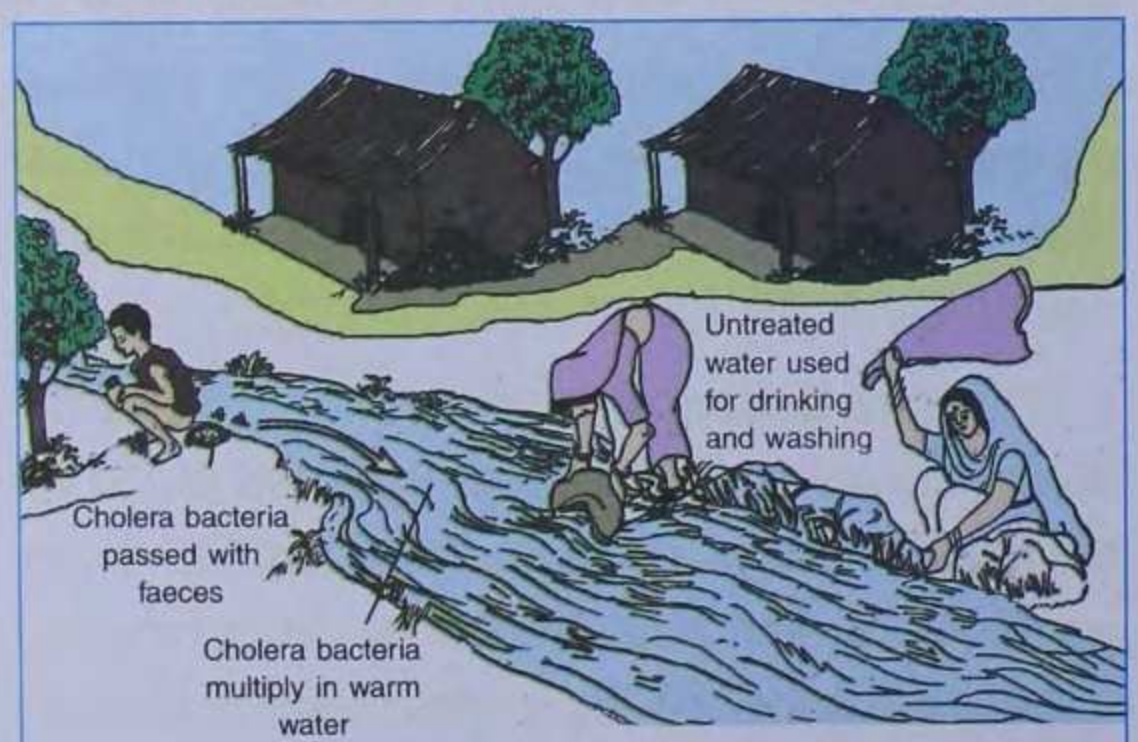


Fig. 5.13

The chemical wastes of factories and fertilizers and pesticides used in agriculture cause **chemical pollution** of water when they are dumped into rivers, lakes, ponds, *etc*.

While hot water from factories and thermal plants when mixed with fresh water cause **thermal pollution**.

5.20 PREVENTION OF WATER POLLUTION

1. We should spread awareness and make sanitary facilities available in rural areas and city slums so as to discourage people from defecating in the open.
2. Domestic sewage should be treated before being discharged into rivers.
3. The solid matter separated from sewage can be used to generate biogas, an important alternative fuel.
4. The waste products of industries should be treated before they are discharged into rivers and other water bodies.
5. We should try to stop using substances like detergents, pesticides, polythene, *etc*. They are non-biodegradable and they pollute the environment, including water, to an undesirable extent.
6. Washing and cleaning of utensils, clothes, bathing of animals and human beings should be avoided near the sources of water like rivers, lakes, *etc*.
7. Trees and plants must be planted along the banks of rivers.
8. Put a covering on the well.
9. Purification of water bodies should be carried out off and on.
10. Dead bodies of animals should be disposed of in a hygienic way.

5.21 EFFECT OF WATER SCARCITY ON PLANTS

You have already learnt that water is needed by plants for various purposes. If water is not available to plants for long the earth will lose its green character.

Human being are dependent on plants. Plants provide food, oxygen, wood and many other useful products. If there are no plants, there will be no life on earth.

5.22 WATER MANAGEMENT

Water is a precious natural resource. In order to make water easily available to us in future, we have to conserve it today. A few ways by which water can be conserved are as follows.

1. Construct dams and reservoirs to control flood and collect water.
2. Do not leave taps running while brushing teeth, shaving or washing clothes.
3. Recycle water in industries and use it as many times as possible, before disposing it.
4. Plant trees to slow down the flow of rainwater on land and to increase seepage of water into soil.
5. Practice rainwater harvesting.
6. Repair leaking taps and pipes at the earliest.

7. Recycle polluted water and use it for irrigation.
8. Use biodegradable fertilizers and pesticides.
9. Farmers should use better methods of irrigation like drip irrigation in which water is supplied to plants drop by drop instead of filling the entire field with water.

RECAPITULATION

- Water is the source of life for all living organisms.
- In Nature, water occurs in all the three states of matter, *i.e.*, ice, liquid and vapour, but mostly in liquid form.
- Water found in nature comes from :
  (i) oceans and seas (ii) rivers and lakes (iii) springs and wells (iv) rain
- Rainwater is the purest form of water. Sea water is very impure, as it contains a very high proportion of dissolved salts.
- Potable water should be free from suspended impurities and harmful germs, but it should contain some dissolved minerals and gases for taste and health purposes.
- Water is a compound with the molecular formula of H_2O.
- The boiling point and the freezing point of water are affected by change in pressure and presence of impurities.
- 0°C is also called triple point because water can exist in all its three states at this temperature.
- The specific heat of water is higher than that of any other liquid. Consequently, it is used as a cooling agent.
- Water has minimum volume and maximum density at 4°C. It starts expanding below 4°C. This is called anomalous behaviour of water.
- Water is an excellent solvent. The gases dissolved in water have biological importance. They enable aquatic life to sustain itself.
- Water may form lather with soap easily, or it may not do so easily. Depending on this, water may be 'soft' or 'hard'. Hardness of water can be removed by boiling or by chemical treatment.
- Water pollution is a serious problem. It is necessary to control water pollution.

EXERCISE – III

1. Define :
   (a) Soft water (b) Hard water
2. What are the causes of temporary and permanent hardness of water ? Suggest one method for the removal of hardness of each type and give chemical equations for them.
3. Differentiate between chemical and thermal water pollutions.
4. What are the main causes of water pollution ? How can it be controlled ?
5. Name three water borne diseases.

OBJECTIVE TYPE QUESTIONS

1. Fill in the blanks :

(a) Water has ..... density and ..... volume at 4°C.

(b) Freezing mixture contains ..... and .....

(c) The solubility of a gas in water .... with rise in temperature and ..... with rise in pressure.

(d) ..... is the purest form of natural water.

(e) Use of artificial ..... by farmers causes water pollution.

(f) Boiling removes the ..... hardness of water.

(g) Water turns the colour of anhydrous copper sulphate .....

(h) Water gas is a mixture of ..... and ..... .

2. State whether the reasons given in column B correctly explain the statements given in column A

Column A	Column B
(a) Acid is added to water before it is electrolysed.	To make it alkaline
(b) Alcohol is mixed with the water used in car radiators	Because it lowers the freezing point of water
(c) Icebergs float in ocean water	Because ice is not a saline substance
(d) Carbonated drinks are bottled under high pressure	Because the solubility of carbon dioxide increases with pressure.

3. Give one word/words for the following statements :

(a) Water fit for human consumption .....

(b) The harmful substances dissolved in water .....

(c) The change of states of water from one form to another .....

(d) The gaseous form of water found in air .....

(e) A mixture of common salt and ice .....

MULTIPLE CHOICE QUESTIONS

1. Two gases dissolved in natural water are
(a) oxygen and carbon dioxide
(b) hydrogen and oxygen
(c) sulphur dioxide and hydrogen
(d) chlorine and ammonia

2. The sticky substance formed when soap is added to hard water is
(a) scum (b) lather
(c) residue (d) precipitate

3. Temporary hardness of water can be removed by
(a) filtering (b) boiling
(c) loading (d) none of the above

4. Water is sterilized by
(a) nitrogen gas (b) oxygen gas
(c) chlorine gas (d) hydrogen gas

5. The ultimate source of all water on the earth is
(a) oceans and seas
(b) spring and wells
(c) rivers and lakes
(d) rain

PROJECT ACTIVITIES

Organize a poster competition in your school for importance of water resources. Also organize a campaign to conserve water

7. Recycle polluted water and use it for irrigation.
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