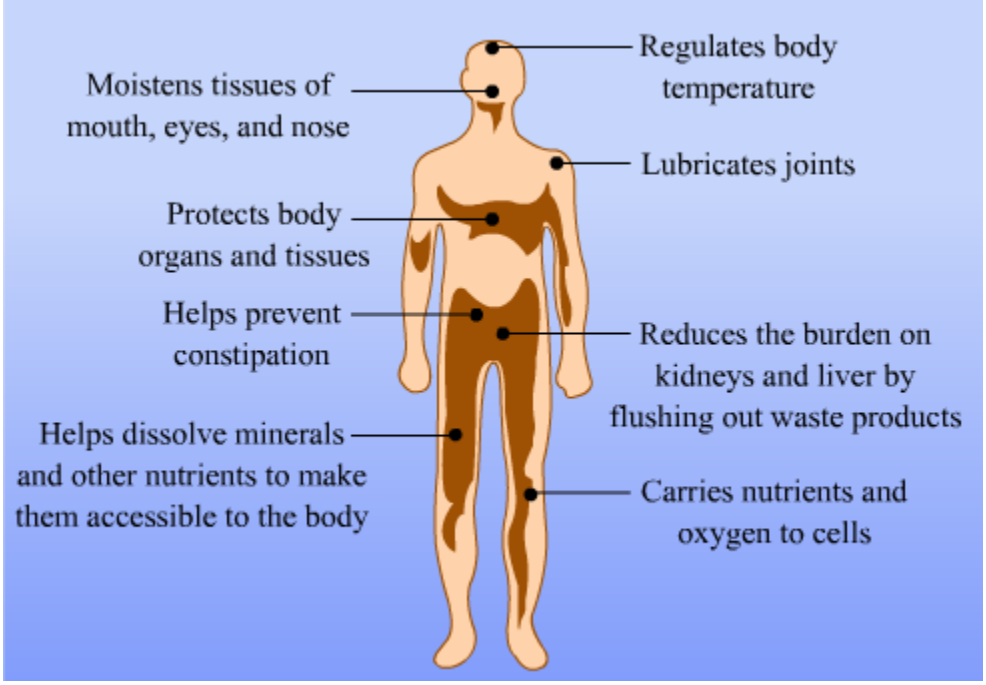
Water

Importance of Water

About 60% of our body is made up of water. Water plays an important role in various vital processes that are carried out by our body. All cellular processes take place in water medium. Read the given graphic to understand the importance of water in our body.



Importance of Water

Water and other life forms

- Aquatic animals live in water. Water is thus central to their lives. Although terrestrial animals live on land, they do need fresh water for carrying out various life processes such as excretion of waste products. Terrestrial life forms require fresh water because their bodies cannot tolerate or get rid of the high amounts of dissolved salts in saline water.

- The availability of water plays an important role in deciding the number of individuals of each species that will be able to survive in a particular area, and also the sustainability of life in the region. The availability of water also decides the diversity of life in that place.

Now you know why the number of animals found in rainforests is high and the number of animals inhabiting deserts is very low!

Fresh water is utilized by humans for consumption. The Municipal Corporation supplies water to our homes. In rural areas, people collect water from different water sources such as wells and ponds to meet their day-to-day requirements.

Know More

Conserving water

One way by which we can help reduce the demand for water is to conserve water round the year.

We can conserve water:

1. By turning off the tap while brushing.
2. By not using more water than what is required while bathing.
3. By closing the tap while washing utensils.
4. By washing vehicles using a mug and a bucket of water and not with a hosepipe.
5. By storing rainwater in tanks or other storage areas for future use.

Uses of Water

Water is very useful in our day to day life. Let's see some uses of water:

1. It is used for drinking.
2. For washing purposes we use water.
3. It is used in fields for irrigation.
4. For bathing we use water.
5. Today, water is also used for generation of electricity.

Sources of Water

Do you know that on an average an individual consumes about 2.9 litres of water everyday?

Water is required not only for drinking but also for many other purposes in our day-to-day lives.

Irrigation in agriculture, industrial processes, domestic purposes such as cooking and cleaning are some of the major uses of water.

What are the sources of water?

We know that water is available from various sources. Some of the common sources of water are ponds, lakes, rivers, wells, and reservoirs.

The water that we use in our homes is supplied from these sources. In villages, people directly use water from the ponds, rivers, lakes, canals, reservoirs etc.

Is water in icebergs salty?

The water in icebergs is not salty, rather it is fresh water. This can be explained by the principle of freezing. Iceberg is the solidified form of water. During the process of solidification the water molecules come close to one another and get packed tightly. This leaves no space for the molecules of salt.

Where does the water in these ponds, lakes, rivers, and wells come from?

Recall a picture of the globe. The area covered by the land is very small as compared to the area covered by water. Water covers two-third (2/3) of the total surface area of the world.

Interestingly, did you know that some of the water from the oceans and seas evaporates and is the primary source of rain? Rainwater feeds into the ponds, lakes, rivers, and wells etc, which in turn are the main sources of water for us.

You may be familiar with instances of the taps in your house running dry for days at a stretch, on account of a shortage of water in your city. We know that there are places in this country where the shortage of water is so severe that people stand in long queues to fetch a few buckets of water! In the villages people have to fetch water from very far distances.

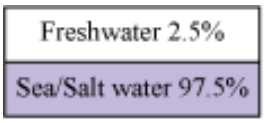
There are numerous fights over water. Marches and protests, against the unavailability of this valuable resource, are fairly common. All these problems are due to the limited availability of fresh water as a resource.

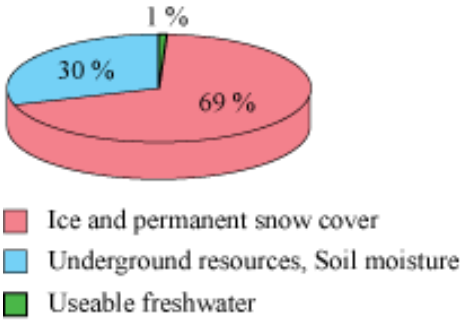
Interestingly, did you know that another name for our planet is '**Blue planet'?** This is because our planet appears to be blue in color when seen from the outer space. This color is because a vast area on Earth is covered with water.

You may know that about 71% of the total surface area of the Earth is covered with water that is contained in the oceans, seas, lakes, rivers, ponds, etc. The remaining 29% is the land surface area. If such a large area is covered with water, then **why is there a scarcity of water?**

Water on the Earth is found in the oceans, seas, lakes, ice caps, rivers, ponds, under the ground, and also in the atmosphere as vapor. The oceans and seas alone account for about 97.5 % of the total water found on the surface of the Earth.

This water from the oceans and seas is not suitable for human consumption as it is salty. The remaining 2.5 % is fresh water and is found trapped in the ice caps, glaciers, ponds, lakes, rivers and underground water that is suitable for use.





Source of fresh water	**Percentage**
Ice and glaciers	69%
Ground water	30%
Surface water	1%

We basically use both surface water and ground water. We obtain ground water by using wells and tube wells.

This is the reason why we face scarcity of water.

Let us perform an activity to understand the amounts of water available in different forms

Collect the items listed below

- A test tube
- A ladle or dropper of 5 ml capacity
- A beaker of 500 ml or larger capacity
- A bucket with a capacity of more than 20 litres
- A small beaker of 150 ml capacity

1.Pour 20 litres of water in a bucket.

These twenty litres of water represents the total water available on Earth.

2.When 100 ladles of water from this bucket is removed it amounts to 500 ml of water. (100 ladles of 5 ml capacity each)

This 500 ml of water in the beaker represents the fresh water available on the Earth.

3.When 30 ladles of water from this beaker is transferred to another beaker, it amounts to 150 ml of water. (30 ladles of 5 ml capacity each)

This 150 ml or 30 ladles full of water represents the usable ground water.

4.When a quarter or $\frac{1}{4}\text{th}$ of this 150 ml of water is removed into another beaker, it amounts to 37.5 ml or 7.5 ladles of water. (A quarter of 150 ml means $\frac{150}{4} = 37.5 \text{ ml}$ of water, i.e. 7.5 ladles of water)

This 37.5 ml or 7.5 ladles represents the water in all lakes, rivers, ponds etc of the world.

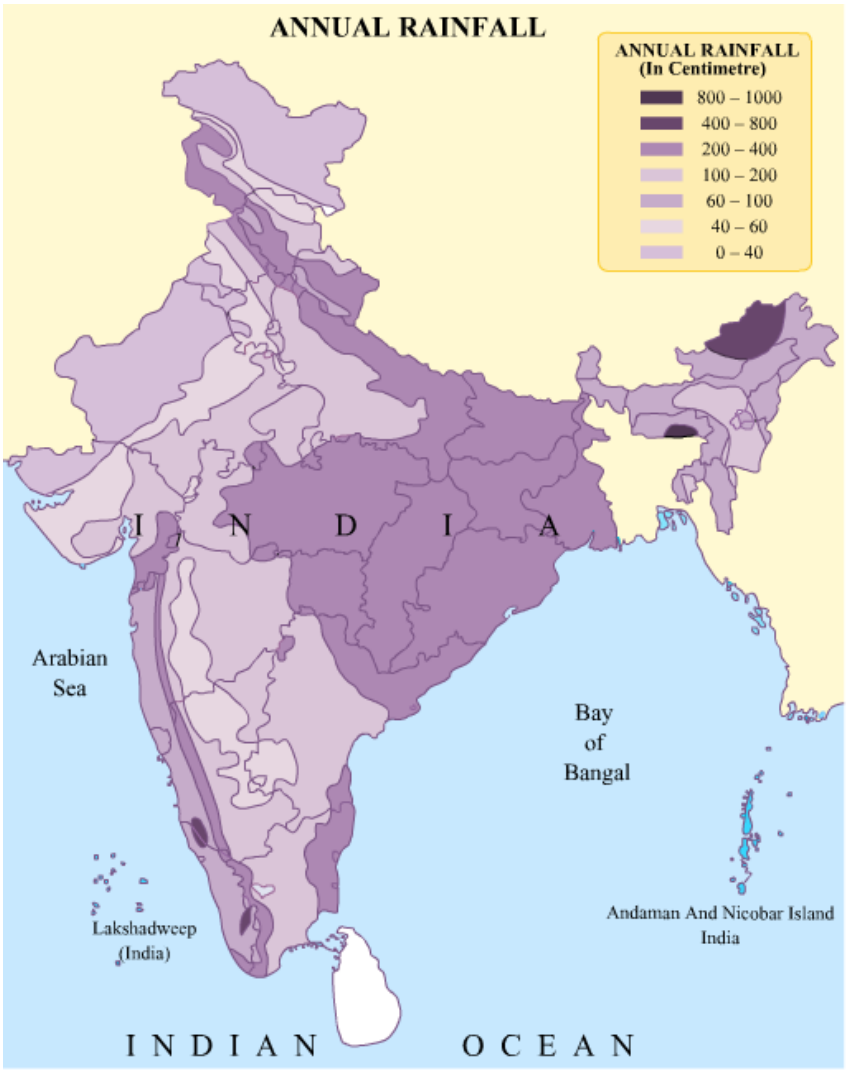
Thus, the quantity of usable water that is available on the Earth's surface is very small in comparison to the total available water on Earth. Therefore, water is indeed a limited resource and should be conserved.

Distribution of Water in India

In India, water availability is greatly dependent on the seasonal monsoons. The distribution of rain water varies in different parts of the country. Some regions such as the north eastern states and the Western Ghats receive excess rainfall while regions of western India such as the Thar desert of Rajasthan do not receive adequate rainfall.

This uneven distribution of rain causes floods in some areas and droughts in the parts where there is scanty rainfall.

The given map shows the average annual rainfall received by the different parts of India.



Water Cycle

Physical States of Water

Water is found in solid, liquid, and gaseous states in the environment. In the solid state, it is found in the form of ice, and as a liquid, it exists as water. It is present as water vapour in the gaseous state.

Physical Properties of Water

- Water is a colourless, tasteless, and transparent liquid. It also has no smell.
- Boiling point of pure water is 100°C at 760 mm of Hg pressure. However, boiling point of water increases due to increase in pressure and presence of dissolved impurities.

- Pure water freezes at 0°C at 760 mm of Hg pressure. However, freezing point of water decreases due to increase in pressure and presence of dissolved impurities.

- The state of water changes on heating or cooling. On heating, the state of water changes from liquid state to gaseous state (vapour). Similarly, on cooling, the state of water changes from liquid state to solid state (ice).

- Pure water is a bad conductor of heat and electricity.

- Water absorbs a fixed amount of heat. It has been found that 1 g of water always absorbs 4.2 J (=1 Calorie) of heat energy when heated through 1°C. This fixed amount of heat energy is called specific heat capacity. Specific heat capacity is the fixed amount of heat energy required to raise the temperature of 1 g of water by 1°C.

  Water undergoes different processes in the environment and is found in different states during these processes. This cyclic process through which water circulates in the environment is called the **water cycle**.

  Let us first describe the process of water cycle for you.

  By now, you know the steps involved in a water cycle. Now, let us look at each step.

  Evaporation

  Have you observed that when the floor is wiped with water, the water dries up in some time? The roads and buildings that become wet after rainfall, dry up soon after. You may have also observed that the water level in a container reduces when it is kept in it for a long time.

  Where is all this water disappearing?

  The process whereby water disappears into air is called **evaporation**. During evaporation, liquid water is converted into gaseous water vapour.

  How does evaporation occur? What are the factors that affect evaporation? Let us understand.

Wet two handkerchiefs and squeeze out the water. Dry one of it outside in the sun and the other inside a room. Observe the time taken for both of them to dry. Do they take the same amount of time?

The handkerchief that was put out to dry in the sun dries up faster than the one inside the room. This is because the heat from the sun speeds up the time taken for evaporation. Thus, ***heat is essential for evaporation.***

Then how did the handkerchief inside the room dry?

This is because the heat from the sun also heated the air inside the room, although indirectly. This warm air converted the water on the handkerchief into vapor. Since direct sunlight did not reach the room, the handkerchief took longer to dry.

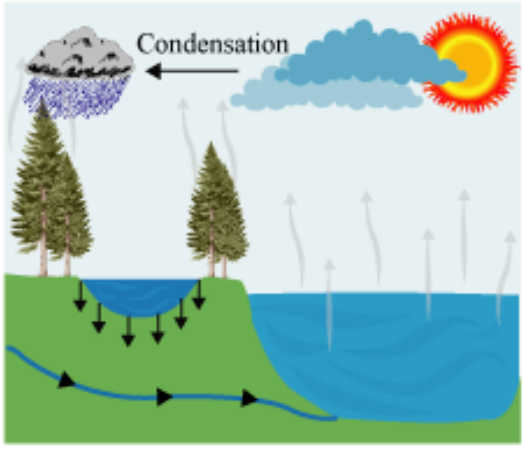
When water is poured over plants kept in pots, it is absorbed by the plant roots. Water is essential for plant growth. The plant utilizes the required quantities of water and the excess water is lost by the surface of the leaves as vapor through the process of ***transpiration.***

Thus, we can say that evaporation and transpiration are the processes by which water is converted into water vapor.

Since sunlight falls on all the water bodies such as oceans, seas, lakes, ponds, and rivers, water is being continuously converted to water vapor. Where does all this water vapor go? Does it disappear forever?

Condensation

As water vapor moves higher up, it cools down and forms water droplets through the process of **condensation**. Many water droplets join together to form clouds.



Precipitation

The water vapour that condenses as clouds falls down as rainfall, snow, or hail by the process of precipitation.

When clouds are large and laden with water, the water begins to fall as **rainfall.**

This rain enters the rivers, ponds, lakes, and other water bodies.

Some of the rainwater that falls on the ground enters the soil and adds to the **groundwater.** The returning of rain water into large water bodies and groundwater is known as **run off**.

This groundwater can be a source of water for the lakes. It can be drawn out using hand pumps and tube wells and utilized. The overuse of groundwater, however, can reduce its availability, thereby increasing water scarcity. When the land surface is covered with concrete, the amount of rainwater that can enter the soil drastically reduces, leading to a further decrease in the availability of ground water.

Thus, we now understand that water enters the atmosphere as water vapor by the processes of evaporation and transpiration. Water vapor condenses to form clouds and falls as rain. Rain water again runs off to large water bodies such as rivers, lakes, oceans, or groundwater.

Rajat wanted to observe the various processes that cause a change in the state of water in the environment. Let us try and mimic the processes.

Did you know that when rainwater flows on the ground, it washes away the valuable top soil? When this top soil is lost, plants cannot grow. This process is called soil erosion.

Water is found in many different states and these states keep changing depending on the temperature and other environmental conditions.

More to perform, observe, and learn

We can observe the processes that occur in the environment in our everyday lives. Do you notice that when water is placed in ice trays and kept in a freezer, it changes into solid ice cubes? Further, when water is heated in a pan, it changes into gaseous vapors.

You may also have observed that on heating water in a container that is covered with a lid, the water vapour cools down after some time to form droplets of water under the lid! When a glass filled with icy cold water is kept on the table, in normal temperatures, small droplets of water are formed over the external surface of the glass.

Physical Properties of Water

A molecule of water is made by the combination of two hydrogen atoms and one oxygen atom.

Do you know that on an average, an individual consumes about 2.9 litres of water everyday?

Water is required not only for drinking but also for many other purposes in our day-to-day lives.

Irrigation in agriculture, industrial processes, domestic purposes such as cooking and cleaning are some of the major uses of water.

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  This fixed amount of heat energy is called specific heat capacity. Specific heat capacity is the fixed amount of heat energy absorbed by 1 g of water, when heated through 1°C.

  What happens when some crystals of copper sulphate are heated?

  The crystals turn white. **Do you know why?**

  This because crystals of copper sulphate contain water and this water is removed on heating. As a result, the salt turns white. This water is called **water of crystallisation**.

  Do you know what water of crystallisation is?

  Water of crystallisation is the fixed number of water molecules present in one formula unit of copper sulphate.

  Hydrated copper sulphate has the chemical formula $CuSO_4.5H_2O$. That is, one formula unit of copper sulphate contains five water molecules.

  Therefore, water of crystallisation of copper sulphate is 5. Similarly, the water of crystallisation of calcium sulphate ($CaSO_4.2H_2O$) is 2.

  Anomalous expansion of water

  Water shows abnormal behaviour when heated or cooled between 4°C and 0°C. If water is cooled below 4°C, then it expands instead of contracting. This abnormal behaviour of water is called **anomalous expansion of water**.

  Water as a solvent

  Water is said to be a **universal solvent**. It can dissolve almost all kinds of substances (solid, liquid, or gas) in it to different extent.

  The substances which dissolve rapidly in water are called soluble substances. Examples include sugar, common salt, etc.

  On the other hand, the substances which do not dissolve or dissolve to very little extent are called insoluble substances. Examples include stones, plastic, glass, etc.

  The respiration and survival of aquatic lives are possible only because of presence of dissolved oxygen in water. Moreover, carbon dioxide gas dissolved in water helps water plants in producing food.

Do you know that the water in the Dead Sea contains 23% to 25% salt. The salt is mainly potassium chloride, magnesium chloride, calcium chloride and calcium bromide. No aquatic life can survive in that much saline water.

Solutions

Whenever we talk about solutions, we instantly think of liquids. **But is it necessary that all solutions are liquids?**

No. A solution is simply a homogeneous mixture of two or more substances. We can also have solid solutions and gaseous solutions. Alloy is an example of a solid solution while air is a gaseous solution.

The only condition that has to be fulfilled for a mixture to be called a solution is that it should have homogeneity at particle level. For example, when sugar is dissolved in water, a solution is obtained because sugar particles are evenly present throughout the solution. As a result, all parts of a sugar solution taste the same.

A solution has two components, namely, the solvent and the solute.

- **Solvent** is that part of the solution in which the other component is dissolved. In other words, solvent is that component of a mixture that is present in large amounts.
- **Solute** is that part of the solution that is dissolved in the solution. This is present in a lesser quantity as compared to the solvent. Also, more than one solute can be present in a solution.

Some common examples of solutions are:

- **Solution of salt in water:** Salt is the solute and water is the solvent.
- **Solution of iodine in alcohol:** Iodine is the solute and alcohol is the solvent. It is also called ‘tincture of iodine’.
- **Vinegar:** Acetic acid is the solute and water is the solvent.
- **Soda water:** CO_2 is the solute and water is the solvent.
- **Air:** N_2 is the solvent and the other gases are the solutes.

Properties of a solution:

- It is a homogeneous mixture of solutes and solvents.
- The solute particles in a solution are extremely small in size. They are less than 1 nm (10^{-9} m) in diameter.
- Solute particles are not visible to the naked eye.
- As a result of the small size of the solute particles, a solution does not scatter light.
- Solute particles being small in size get dissolved in the solvent. Hence, the solute cannot be separated from the solution by filtration.
- Solute particles do not settle down when left undisturbed.

Solubility

The amount of a solute present in its saturated solution at a given temperature is called the solubility of the solute at that temperature.

For example, if 30 g of a substance dissolves in 100 g of water at 25°C, then the solubility of the substance is 30 g/ 100 g of water at 25°C.

Mathematically, solubility of a substance is given by,

$$\text{Solubility of solute} = \frac{\text{Weight of solute (in g)}}{\text{Weight of solvent (water) (in g)}} \times 100$$

With an increase in the temperature of a solution, the solubility increases. This can be easily demonstrated as shown in the following animation.

Solubility

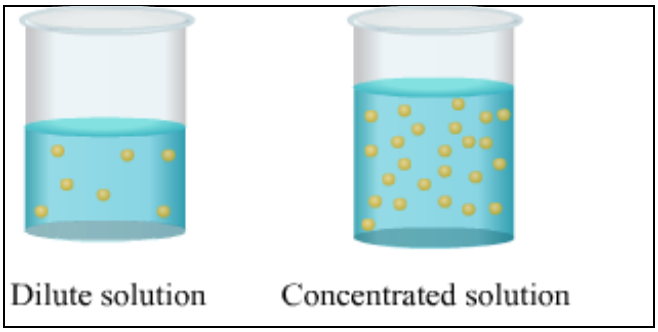
In general, solubility refers to the dissolution of solute in solvent. **But is it possible to dissolve high quantity of solute in a small quantity of solvent?** The answer is no.

Hence, to be more precise, solubility is defined as the dissolution of solute in particular amount of solvent.

Sometimes when the quantity of salt is less in your food, you put some more salt to improve its taste. Doing so, you actually increase the concentration of salt in your food. The term ‘concentration’ means the amount of solute dissolved in a particular amount of solvent.

While performing tests in chemistry lab, you must have come across diluted and concentrated solutions of acids and bases.

A solution in which the amount of solute dissolved is high is called a **concentrated solution** and a solution in which the amount of solute dissolved is low is called a **diluted solution**.



Now, how much solute can a particular amount of solvent dissolve?

When the maximum amount of solute is dissolved in particular amount of solvent, it forms a saturated solution. For example, solubility of common salt in 100 ml of water is 35.7 g at 20˚C. It means that no more salt can be added in 100 ml of water at 20˚C.

But the quantity of salt can be increased if the solution is heated. Thus, we can say that solubility increases with an increase in temperature. Different substances have different solubility at the same temperature.

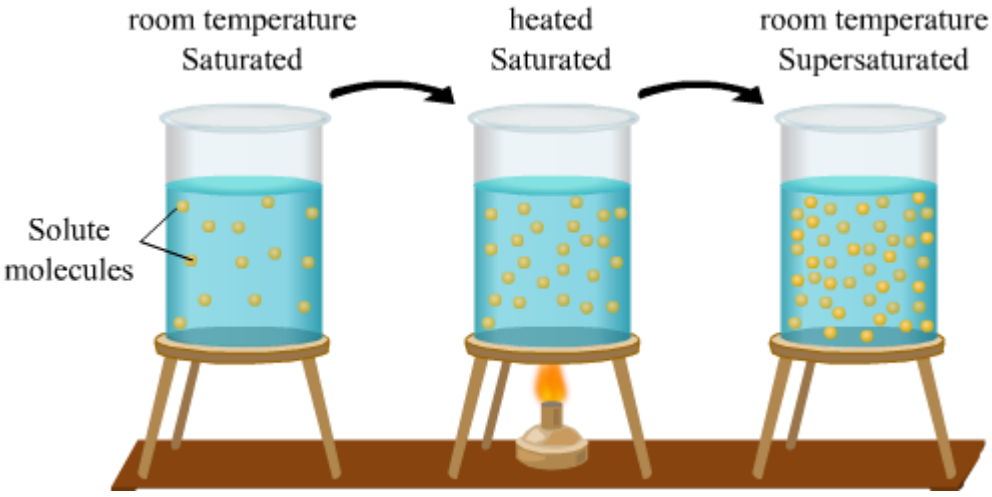
As discussed above, saturated solutions are those which contain the maximum amount of solute in a fixed amount of solvent but if the temperature of this solution is increased, then more quantity of the solute can be added.

If the solution is allowed to cool down at room temperature and there is no precipitation of solute, then the resulting solution is called **supersaturated solution**.

Let us perform an activity to understand the concept of supersaturated solution.

Activity

Take a beaker containing 100 ml of water and add salt in it while stirring the solution. Keep on adding salt till no more salt can be dissolved. After attaining the saturation point of solvent, warm the beaker and try to add more salt in it.



What do you observe?

After heating the beaker, more salt can be added into it.

What kind of solution do you get after performing the above experiment?

The solution which is obtained is called a supersaturated solution.

Activity

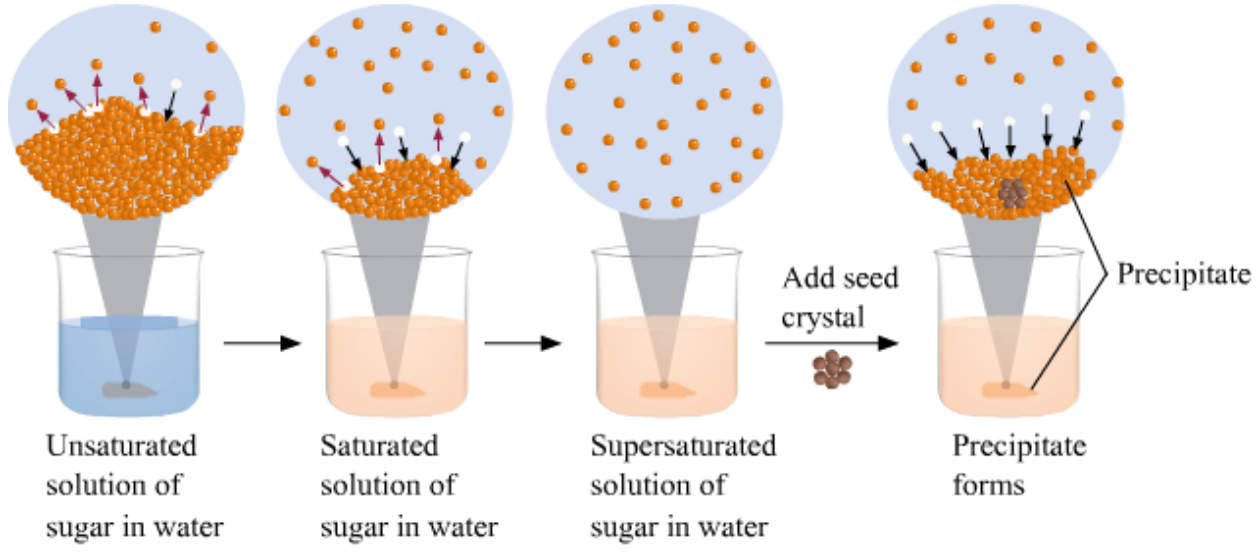
Take 100 ml water in a beaker. Add sugar in it and make a supersaturated solution of sugar. Now add a sugar cube into the beaker.

What do you observe?

The size of sugar cube increases.

What could be the possible explanation behind this observation?

The supersaturated solution gets disturbed when a sugar crystal is added in it as it tries to return back to its saturated state. Thus, when a crystal is added in such a solution, the deposition of the extra solute on the crystal starts. This process is known as crystallisation.



Water of Crystallization

We know that washing soda is produced by mixing water and sodium carbonate. The molecular formula of washing soda is $Na_2CO_3.10H_2O$.

Sodium carbonate is obtained by heating sodium hydrogencarbonate.

$$\underset{\text{(Sodium Hydrogen carbonate)}}{2NaHCO_3} \rightarrow \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O + CO_2$$

The re-crystallization of sodium carbonate then produces washing soda.

$$Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3 \cdot 10H_2O$$

Ten water molecules are present in the formula of washing soda. These water molecules are called **water of crystallization.**

Water of crystallization refers to a fixed number of water molecules present in one formula unit of salt.

The following experiment will help in understanding the concept of water of crystallization.

Aim: To prepare crystals of copper sulphate ($CuSO_4$)

Material required: Beaker, distilled water, copper sulphate ($CuSO_4$) crystals, glass rod, thread, watch glass

Theory: Water of crystallization imparts the characteristic blue colour to copper sulphate ($CuSO_4$) crystals. These crystals are obtained by the process of *seeding*. In this process crystallization is induced with the help of small crystal of pure hydrated copper sulphate ($CuSO_4.5H_2O$) which is added in the saturated copper sulphate solution.

Procedure:

1. Take a beaker and prepare a saturated solution of copper sulphate ($CuSO_4$) at 80^o C and filter the solution to remove any undissolved impurity.
2. Cover the filtrate with watch glass.
3. Cool down the filtrate and leave it undisturbed for 24 hours.
4. Some crystals of copper sulphate ($CuSO_4.5H_2O$) will be formed at the bottom of the beaker. Collect a few of them.
5. Suspend one of the well formed small crystal in the saturated solution by tying to a glass rod using a thread.

6. Again cover the beaker with watch glass to avoid dust entering the solution.
7. Leave it undisturbed.

Observation: The suspended crystal grows in size with each passing day.

Water of crystallization is the fixed number of water molecules present in one formula unit of salt.

It is in chemical combination with a crystal
It is necessary for the maintenance of crystalline properties of the crystal
It can be removed by sufficient heat

The following experiment shows the effect of heat on solids that do not contain water of crystallisation.

Aim: To show effect of heat on solids that do not contain water of crystallisation.

Material required: Test tube, burner, potassium nitrate (KNO_3)

Theory: Not all crystalline solids contain water of crystallisation. These solids when heated decompose to form new compounds.

Procedure:

1. Take some potassium nitrate crystals in a test tube.
2. Heat the tube gently.

Observation: The crystals form a colourless solution giving off a gas, that bursts the glowing splinter. It signifies that oxygen is being involved. In the end, a pale yellow residue is left in the test tube.

$$\underset{\text{Potassium nitrate}}{2\ KNO_3} \xrightarrow{\Delta} \underset{\text{Potassium nitrite}}{2\ KNO_2} + O_2$$

Hydrated Substances

Those substances which contain water of crystallization like hydrated copper sulphate ($CuSO_4.5H_2O$), are called hydrated substances. The water of crystallisation gives their crystals shape and in some cases colour.

Gypsum is another salt that possesses the water of crystallization. It has a chemical

formula of $CaSO_4.2H_2O$. It is also known as hydrated calcium sulphate.

When hydrated calcium sulphate ($CaSO_4.2H_2O$) or gypsum is heated at 373K, it loses its water molecules and forms calcium sulphate hemihydrate ($CaSO_4.\frac{1}{2}H_2O$). **This hemihydrate form of calcium sulphate is known as Plaster of Paris.** It is in the form of a white powder.

When the powder of Plaster of Paris is mixed with water, it becomes hard and solid gypsum. Plaster of Paris is generally used to support fractured bones in their correct positions.

$$\underset{(\text{Plaster of Paris})}{CaSO_4.\frac{1}{2}H_2O} + 1\frac{1}{2}\ H_2O \rightarrow \underset{(\text{Gypsum})}{CaSO_4.2H_2O}$$

In $CaSO_4.\frac{1}{2}H_2O$**,** only half a water molecule is shown as the water of crystallization because two formula unit of $CaSO_4$ share one molecule of water.

Plaster of Paris is used for making toys, materials for decoration, and for making smooth surfaces.

Determination of Water of Crystallization

Heat a known weight of a hydrated substance to a temperature above 100° C. Weigh the residue. Repeat these two steps, till the weight of the residue becomes constant. Use the following formula to obtain the percentage of water of crystallization in a link:

Initial weight of the hydrated substance = *x* g
Final constant weight of the substance after heating = *y* g

$$\%\ \text{of water of crystallization} = \frac{x-y}{x} \times 100$$

Anhydrous Substances

Those substances which do not contain any water of crystallization or the substances from which the water of crystallization have been removed like sodium chloride (NaCl) are called anhydrous substances.

The water of crystallization can be removed by using any of the following methods:

- Direct heating of the hydrated substance

- Heating the hydrated substance in dry and hot air
- Heating the hydrated substance under vacuum
- Using dehydrating/desiccating agents

Drying Agents

The substances that absorb moisture from other substances without undergoing a chemical reaction with them are called drying agents or desiccants or desiccating agents. Examples of drying agents are anhydrous calcium chloride, anhydrous zinc chloride etc.

Most of the hygroscopic substances are desiccating agents like concentrated sulphuric acid, silica gel etc.

The following table illustrates the techniques used to dry certain substances.

Substance	Drying technique
Gases	By passing through concentrated sulphuric acid Used for drying acidic gases like HCl gas By passing through a drying tower or a U-tube containing anhydrous sodium sulphate By passing through a drying bulb containing anhydrous calcium chloride
Liquids	By keeping them over anhydrous sodium sulphate or calcium chloride for over a night After this, solid is removed by filtration.
Solids	By placing them in a desiccator (air-tight vessel with a drying agent like calcium chloride spread at the bottom)

Dehydrating Agents

The substances that can remove chemically bounded water from compounds are called dehydrating agents. Concentrated sulphuric acid is a strong dehydrating agent. It can remove water molecules from hydrated copper sulphate ($CuSO_4.5H_2O$).

$$\underset{\text{(blue)}}{CuSO_4.5H_2O} \xrightarrow{Conc.\ H_2SO_4} \underset{\text{(white)}}{CuSO_4} + 5H_2O$$

The following table explains the differences between drying agents and dehydrating

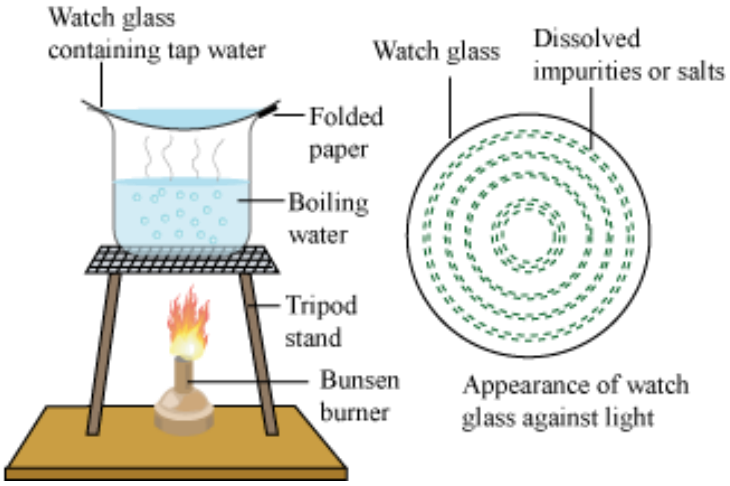
agents.

Drying Agents	Dehydrating Agents
Removes moisture from other substances	Removes chemically bounded water molecules from substances
Performs a physical change in the substance	Performs a chemical change in the substance

Chemical Properties of Water

Experiment to show the presence of dissolved solids in tap water

Take some tap water in a 100 mL beaker and heat it. Place a large watch glass over the beaker and raise the edge of the watch glass from one side by placing a folded paper (as shown in the figure). Then pour about 10 mL of tap water into the watch glass.



What have you observed?

You will observe that the steam produced from the boiling water in the beaker starts evaporating the water in the watch glass slowly.

Let the water in the watch glass evaporate completely. Then, remove the watch glass from the beaker and look through it against light.

Can you see some concentric rings of fine solid materials sticking to the watch glass?

The tap water contains some dissolved solids. As the water evaporates slowly, the dissolved solids deposit and as a result, the concentric rings of the solid materials are formed.

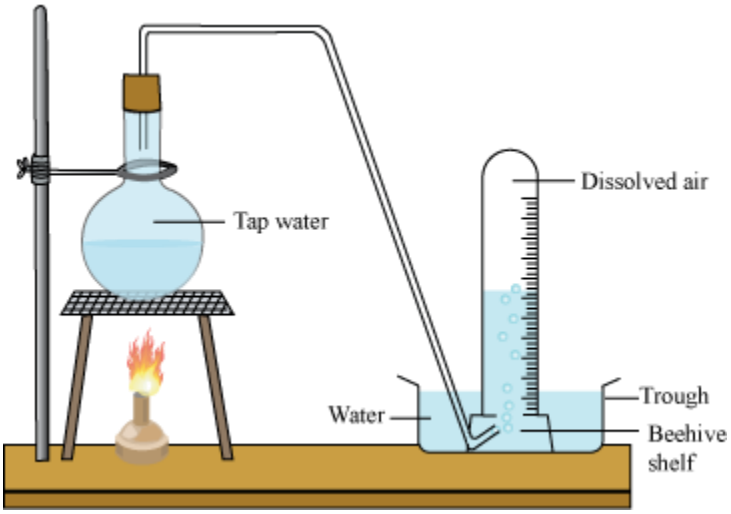
Why are the dissolved salts in water important?

The dissolved salts in water are important because of the following reasons:

- They provide taste to water.
- They are required by our body as they provide nutrients for growth, repair, and development of cells.
- Their deficiency may cause a number of diseases.

Experiment to Show the Presence of Dissolved Gases in Tap Water

Take some tap water in a round bottomed flask and fill it completely. Fix a cork fitted with a delivery tube in mouth of the flask. The lower end of the delivery tube should be in line with under-surface of the cork. Its other end should be in the beehive shelf, placed in a trough of water. Set up the apparatus as shown in the figure.



Heat the water in the round bottomed flask. After some time, some tiny bubbles of gas coming out of the water are observed. If the heating is continued, then water starts boiling and the gas bubbles start coming out of the beehive shelf.

Lower the flame to keep the water just near the boiling point. Then invert a graduated tube completely filled with tap water over the beehive shelf. The boiled off air starts collecting in the tube by replacing water.

Collect the tube filled with boiled off air and introduce a glowing splinter in it.

What have you observed?

The glowing splinter will burst into flames. This is possible only when the boiled off air contains more oxygen than atmosphere. Now, it can be concluded that oxygen is dissolved in water. Similarly, gases such as nitrogen, carbon dioxide are also dissolved in water.

Importance of dissolved gases in water

Similar to dissolved solids, dissolved gases (especially oxygen and carbon dioxide) in water are also important.

Dissolved oxygen in water is important because of the following reasons:

- It is required by animals living in water during their respiration, without which they cannot survive.

$$\underset{\text{Glucose}}{C_6H_{12}O_{6(s)}} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(l)} + \text{Heat}$$

- It helps to keep water purified by killing germs and bacteria.

Dissolved carbon dioxide in water is important because of the following reasons:

- It is required by water plants during photosynthesis.

$$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow{\text{Sunlight}} \underset{\text{Glucose}}{C_6H_{12}O_{6(s)}} + 6O_{2(g)}$$

- Dissolved carbon dioxide reacts with limestone to form soluble calcium carbonate, which is used by animals living in water to form hard shells for the protection of their soft bodies.

$$\underset{\text{Limestone}}{CaCO_{3(s)}} + H_2O_{(l)} + CO_{2(g)} \longrightarrow \underset{\text{Calcium carbonate}}{Ca(HCO_3)_{2(aq)}}$$

Do you know how metals react with water?

Let us see.

Reaction with Sodium and Potassium

Sodium and potassium react violently even with cold water. When a small piece of sodium or potassium is dropped into a trough of cold water, it reacts with water and burns with a bright flame.

During this reaction, respective metal hydroxides are formed with the evolution of hydrogen gas.

$$Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH_{(aq)} + H_{2(g)}$$

Reaction with Calcium

Calcium reacts very quickly with cold water forming calcium hydroxide with the evolution of hydrogen gas.

$$Ca_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

Reaction with Magnesium

Magnesium does not react with cold water. However, it reacts slowly with hot water. Also, it burns by reacting with steam for a few moments and then the reaction stops.

$$Mg + H_2O \rightarrow MgO + H_2 \uparrow$$

Reaction with Iron

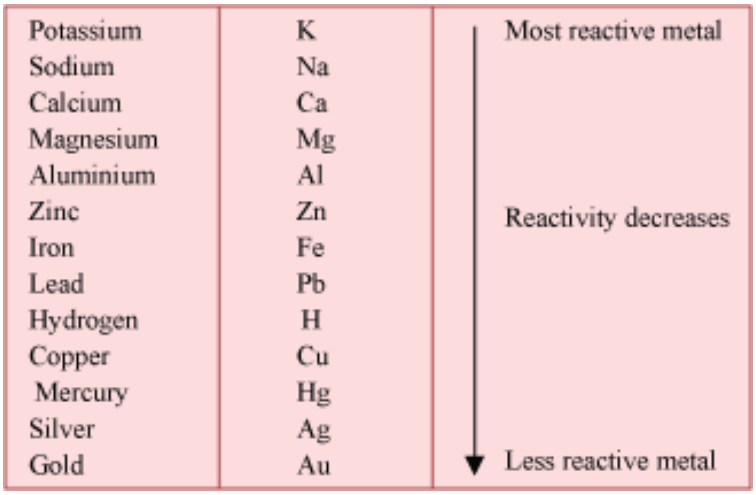
Iron does not react with either cold water or hot water. It reacts with steam reversibly when heated (above 800 °C) to form ferrosoferric oxide and hydrogen.

$$3Fe_{(s)} + 4H_2O_{(g)} \xrightarrow[\text{Above } 800^\circ C]{\Delta} Fe_3O_{4(s)} + 4H_{2(g)}$$
$$(\text{Red hot})$$

Reactivity Series

Metals can be arranged in an order of decreasing reactivity after observing their rate of reactions with water, resulting in the reactivity series.

Reactivity series is a series in which metals are arranged in decreasing order of their chemical reactivities as shown below.



Distillation of water

Tap water and borewell water has a taste due to the presence of dissolved salts in it. Water can be made pure by the process of "**Distillation".** In this process, water is heated till it evaporates and water vapour is then collected in the receiver tube.

Water vapour then condensed by cooling water, salts and minerals which do not vapourise remain in the flask. Thus water free from any salts and minerals is known as distilled water. Distilled water is pure water.

Know this: Although distilled water is pure water, yet it should not use in drinking purposes. This is because distilled water do not contain any salts and mineral which are required by our body and therefore not suitable for drinking purpose.

Hygroscopic nature of water: Hygroscopic nature if the ability of a substance to hold the water molecules from its surroundings either by absorbing or by adsorbing.

When some salts dissolved in water, they tend to absorb water molecules, this property is termed as **Deliquescence**.

Deliquescent substances are those materials which have a great tendency to absorb moisture in a large amount.

For example: Zinc chloride, calcium chloride, potassium hydroxide etc.

Efflorescence: It is the loss of water of crystallization from a hydrated salt to the atmosphere.

For example: Gypsum ($CaSO_4.5H_2O$) is a hydrated salt and in dry environment it loses all its water molecules and form anhydrous salt $CaSO_4$.

Soft and Hard Water

Water is a very precious natural resource found only on earth. Pure water is colourless, tasteless and odourless. It gets colour, odour and taste due to the presence of salts like nitrates, sulphates, chlorides and bicarbonates.

The presence of these salts further affects the property of soap. Water is thus classified into soft water and hard water on the basis of its interaction with soap.

• **Hard water:** Presence of Ca^{2+} and Mg^{2+} ions/salts in water causes formation of insoluble scum rather than foam with soap. This type of water which does not form lather with soap is known as ***hard water***.

• **Soft water:** Water which is free from salts of calcium and magnesium, and gives lather with soap easily is known as ***soft water***.

• When water is free from the presence of any ions/salts, it is known as ***distilled water***.

Note: Salts of metals like iron, manganese and those of other divalent metals can also cause hardness of water.

Reason for the formation of scum:

Soap is a sodium or potassium salt of higher fatty acids (fats). When it reacts with soft water, it easily dissociates into ions and forms lather. But when water contains Ca^{2+} and Mg^{2+} ions, soap reacts with these ions to form insoluble precipitates of calcium and magnesium salts of higher fatty acids and does not form lather.

$$\underset{\text{soap}}{2\,H_3C(CH_2)_nCOO^-\,Na^+} \xrightarrow{M^{2+}} \underset{\text{insoluble scum}}{(H_3C(CH_2)_nCOO^-)_2M} + 2\,Na^+ \qquad [M^{2+} = Ca^{2+}, Mg^{2+}\ \text{ion}]$$

Types of hardness of water:

Hardness of water can be divided into two categories:

• **Temporary hardness:** When water contains bicarbonates of calcium and magnesium [$M(CO_3)$, M = Ca^{2+}, Mg^{2+} ion], they can be removed by simple methods like boiling. This type of hardness is known as temporary hardness.

• **Permanent hardness:** When chlorides and sulphates of calcium and magnesium [MCl_2 and MSO_4, M = Ca^{2+}, Mg^{2+} ion] are present in water, they cannot be removed by

simple methods; they require special methods for their removal. This type of hardness is known as permanent hardness.

Advantages of hard water:

- It tastes better because of the presence of salts and hence, is used in making beverages and wines.
- Salts of magnesium and calcium present in hard water are required for growth of bones and teeth.
- It checks the lead poisoning by lead pipes as it forms a layer inside the lead pipe and does not let lead mix up with passing water.

Disadvantages of using hard water:

• **Household use:** Water is used in a number of household activities, like washing, bathing, drinking, cooking, etc. If hard water is used in these activities, lather is not formed.

It also makes the skin dry and leaves stains on utensils and clothes. Food cannot be cooked properly. Using hard water causes accumulation of salts on the inner walls of containers and makes their cleaning difficult.

• **Industrial use:** Hard water used in various industries like paper, printing, dye and textile, etc. causes great difficulties. Boilers used in these industries get scales on their inner walls due to accumulation of insoluble carbonates formed from calcium and magnesium bicarbonates (temporary hardness).

Note: These days temporary hardness and permanent hardness are referred to as carbonated hardness and non-carbonated hardness respectively.

Methods of Softening Hard Water

Temporary hardness:

• **Boiling:** Since, temporary hardness is due to presence of soluble bicarbonate salts of calcium and magnesium, these upon boiling are converted into insoluble carbonate salts which can be removed by filteration.

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$ (g)

soluble insoluble

Also, $Mg(HCO_3)_2 \rightarrow MgCO_3 + H_2O + CO_2$ (g)

soluble insoluble

Although this method is quite simple, but for softening large quantities of water requires huge amount of energy and consumes too much time.

• **Clark's method:** This method is used at industrial scale to remove temporary hardness of water. In this method calculated amount of lime [$Ca(OH)_2$] is added to hard water, which converts soluble bicarbonates to insoluble carbonates.

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2\ CaCO_3\downarrow + 2\ H_2O$

$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow MgCO_3\downarrow + CaCO_3 + H_2O$

Permanent hardness:

• **Distillation:** During distillation of water both temporary and permanent hardness are removed. In this method water is heated which converts it into its vapour. These vapours are condensed and collected in a separate container to obtain pure water. Hence water obtained after distillation is soft as well as pure.

• **Washing soda process:** In this method calculated amount of washing soda (Na_2CO_3) is added to hard water which removes both temporary and permanent hardness by converting chloride, sulphate and bicarbonate salts into insoluble carbonates which are easily removed by filtration.

$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

$MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$

$MgCl_2 + Na_2CO_3 \rightarrow MgCO_3 + 2NaCl$

$Ca(HCO_3)_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaHCO_3$

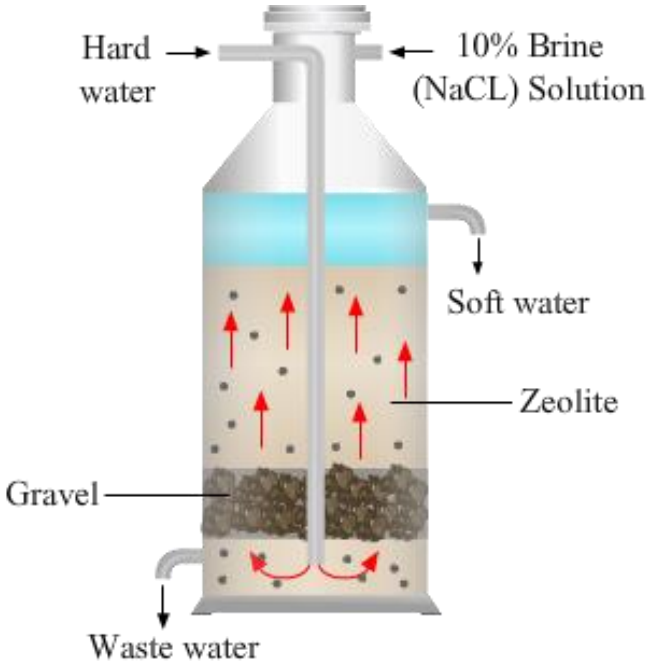
$Mg(HCO_3)_2 + Na_2CO_3 \rightarrow MgCO_3 + 2NaHCO_3$

• **Permutit method:** This is a new method of softening hard water by using hydrated sodium aluminium silicate ($Na_2Al_2Si_2O_8.xH_2O$) alos known as **permutit**. Naturally occurring sodium aluminium silicate is known as **zeolite**.

(i) It is used in the form of a porous gel and is prepared by heating sodium silicate and sodium aluminate.

(ii) In this method soluble salts of calcium and magnesium are converted into insoluble calcium and magnesium permutits by exchanging the Ca^{2+} and Mg^{2+} ions with base ion Na^{+} of sodium aluminium silicate (zeolite).

This is done by passing hard water through the layers of zeolite or permutit as shown in the figure given below:



(iii) In the column given in the figure, sand, gravel and permutit are placed in alternate layers through which hard water flows down. As water passes, Ca^{2+} and Mg^{2+} ions are exchanged with Na^{+} ions of the permutit. This forms calcium and magnesium permutit leaving behind only pure water.

Sodium permutit + $CaCl_2$/$Ca(HCO_3)$/$CaSO_4$ →

Calcium permutit + NaCl/$NaHCO_3$/Na_2SO_4

(iv) Calcium/magnesium permutit thus obtained is further converted into sodium permutit by reacting it with 10% NaCl solution and hence it can be recycled.

Calcium/magnesium permutit + NaCl → Permutit + $CaCl_2$/$MgCl_2$

(v) This process is widely used for removal of hardness water, but this method does not work if certain ions like lead, iron or manganese are present which does not exchange themselves with sodium ions.

Thus water obtained by this method is soft water but not pure water.

Water Pollution

The addition of harmful substances to water, as a result of which its physical, chemical, and biological properties get altered, is called ***water pollution****. The substances that pollute water are called water pollutants.* Sewage, toxic chemicals, silt etc. are examples of water pollutants.

What effect does water pollution have on living organisms? Let us explore the effects of various water pollutants on living organisms.

Water pollutants:

There are three main categories of water pollutants:

Biological pollutants: Biological pollutants make the water unfit for consumption and are responsible for causing various kinds of diseases, for example, algae, bacteria, fungi, etc.

Inorganic pollutants: These include suspended particles like dust, sand, soil etc.

Organic pollutants: These include weedicides, pesticides, fertilizers, sewage etc.

Do you know that water pollution can occur either through natural reasons or man made reasons?

Natural reasons of water pollution include the presence of aquatic weeds, decomposing matter, mud/sludge, algae or nematodes. Presence of these components in water bodies makes them unfit for human consumption.

Man made reasons of water pollution include industrial wastes, pesticides etc. Lets study them in detail.

Industrial waste

In the absence of proper treatment facilities for industrial wastes, most of these wastes are directly dumped into the rivers. The industrial wastes from oil refineries, chemical factories, sugar mills, and fertilizer plants carry toxic substances such as arsenic, lead, mercury, and fluoride. These substances cause toxicity in plants and animals.

They also pollute the soil by increasing its acidity, decreasing its fertility, and affecting the growth of worms which are beneficial for the soil.

Pesticides and fertilizers

We know that fertilizers and pesticides are the farmer’s friends as they help in killing the pests and weeds and increasing the fertility of the soil. **However, do you know that**

they also have a significant negative impact on the water bodies?

The chemicals that are contained in these pesticides and fertilizers get dissolved in the water and eventually get washed away to the water bodies. They also seep into the ground and pollute the ground water.

On entering the water bodies, these pesticides and fertilizers increase the nutrient content of the soil as they contain various nutrients. This accelerates the growth of algae in the water bodies.

You may have observed that some water bodies appear green in colour. This is because of the excessive growth of algae in water. **Does this excessive algal growth have any effect on the living organisms present in the water body?** The answer is a yes.

When these algae die, they are decomposed by the action of micro-organisms that are present in water. Consequently, the number of these micro-organisms in water bodies increases.

Since they consume a large quantity of oxygen that is present in the water, it leads to a decrease in the levels of oxygen. The absence of oxygen eventually leads to the death of the living organisms.

Sewage

Sewage is waste water that contains faecal matter, urine, food wastes, detergents, and other solid substances. Sewage contains many disease-causing pathogens such as bacteria, fungi, viruses, and parasites. When drinking water gets contaminated with sewage water, these harmful organisms enter the bodies of the living organisms and cause several diseases.

Some of the diseases caused by the drinking of contaminated water and the names of the respective causal organisms are listed in the given table.

Name of the disease	Causal organism
Cholera	Bacteria
Typhoid	Bacteria
Diarrhoea	Bacteria
Hepatitis	Virus
Amoebic dysentery	Protozoan

Several bacteria are present in the faeces of mammals. If the water is contaminated with faeces, then these bacteria function as indicator organisms for the quality of water i.e., the number of these faecal bacteria indicates the extent to which the water is contaminated by faecal matter.

Release of Superheated Water

The release of superheated water from some industries and nuclear power plants causes thermal pollution of the water bodies.

It results in the increase in temperature of ambient water that reduces dissolved oxygen content of water bodies. The abrupt change in the temperature of water body can kill the fish and other organisms adapted to particular temperature range.

Release of Waste and Oil from Refineries

The wastes and oil released from the refineries mainly in the seas and oceans cause marine pollution. The released oil penetrates into the plumage of birds and fur of mammals. This reduces their insulating ability and makes them more vulnerable to temperature fluctuations.

Methods of preventing water pollution

- Industrial waste must be chemically treated to remove harmful substances before dumping into the water bodies
- Disposal of human and animal excreta into water should be avoided
- Sewage water must be treated before releasing into the rivers
- Dumping of dead bodies, carcasses and other wastes into the water must be stopped
- Aquatic animals like tortoise and some special types of fishes help in purifying water, therefore they are termed as natural purifier of water

Some Interesting Facts:

- According to the Central Pollution Control Board, about 3,684 million litres of sewage is produced in Delhi in a single day.
- *Escherichia coli* bacterium, which is present in the faeces of humans and other living organisms, is used as an indicator organism for water contaminated with faeces.

Steps To Make Water Available To All

Water is a necessity for every form of life. It is used for domestic purposes, irrigation, navigation, industrial purposes, etc. Areas that encounter acute shortage of water are also areas that face severe poverty and underdevelopment.

There are various sources of water. Rainfall is one of the primary sources of water. Our country receives rainfall during the monsoon season. An adequate amount of rainfall helps to increase the level of groundwater.

However, despite water being abundantly available, we have failed to sustain its availability throughout the year because of several reasons. Some of these are listed below.

- In order to **meet the demands of a growing population**, water is overdrawn from water bodies such as ponds, lakes, rivers, etc. This results in the drying up of these sources of water.

- The amount of **groundwater being drawn for use by humans is more than the amount of water being replaced through rainfall**. This has resulted in the depletion of groundwater. In some areas, the groundwater level has gone down drastically.

- Very **little water seeps through the ground** because of a lack of adequate vegetation cover.

- The availability of usable water resources is diminishing as a result of an **increase in water pollution levels**. This is primarily caused by the discharge of sewage and industrial wastes into water bodies.

In India, the irrigation and conservation of water through the construction of dams, canals, and tanks are age-old practices. These methods of irrigation and conservation of water are based on the traditional models.

These practices are essentially governed by the requirements of the local people, who try to ensure that their minimum water requirements for agriculture and other daily requirements are met throughout the year.

The coming of the British to India saw the construction of large scale dams and big canals covering long distances. These large scale irrigation and water conservation methods are not based on the traditional models.

The administration and governance of such large scale projects are in the hands of the government and not in the hands of the local people. This causes improper and unequal distribution of water in certain areas.

People living near a source of water i.e., near a canal or a dam grow water-intensive crops such as paddy and sugarcane while those living down the stream do not get any water.

Rivers, lakes, ponds, oceans, and glaciers are some of the other sources of water. These sources are rapidly diminishing because of an increase in population and rising levels of water pollution.

The phenomenon of global warming is primarily the result of industrialization and deforestation. It disturbs the natural water cycle, which results in changes in the pattern of rainfall.

Methods of conservation

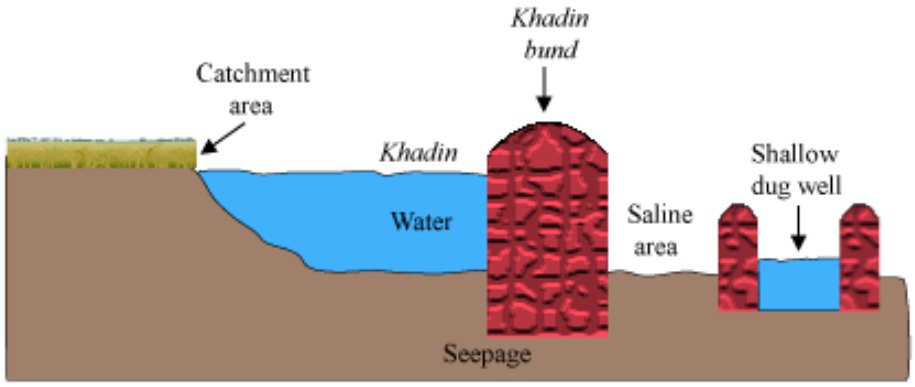
Rainwater is essential for ensuring the availability of usable water. Let us watch the following animation to understand why rainwater harvesting is important and how it can be done?

Rainwater harvesting has been in practice in rural India since a very long time.

Small pits, lakes, earthen dams, sand and limestone reservoirs, and rooftop water collecting units are some of the well-known structures that are used for collecting rainwater. The underlying concept is to make rainwater percolate below the ground, so that the level of groundwater gets replenished.

The following table lists the local names of some water harvesting structures.

Region	**Water harvesting structure**
Bihar	Ahars and Pynes
Himachal Pradesh	Kulhs
Karnataka	Kattas
Kerala	Surangams
Madhya Pradesh and Uttar Pradesh	Bundhis
Maharashtra	Bandharas, Tals
Rajasthan	Khadin, Tanks, Nadis
Tamil Nadu	Eris (Tanks)



The traditional rainwater harvesting method used in Rajasthan is based on the principle of harvesting rainwater in farmlands.

In this method, saturated water is used for crop production and the surface run-off water is harvested for agriculture.

This method mainly consists of an earthen embankment (known as *khadin*), built across the lower slopes of the hills.

A cemented wall (known as *khadin bund*) is built to hold the water in the *khadin*.

Advantages of rainwater harvesting

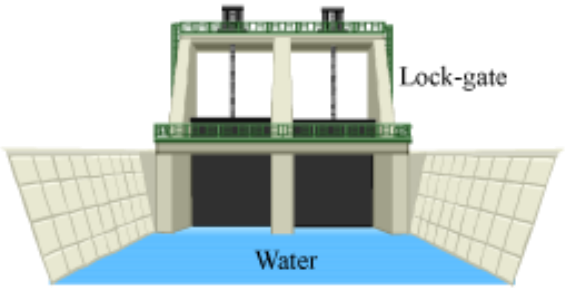
- Water does not evaporate. Instead, it percolates into the ground, thereby resulting in the recharging of wells.
- The stored water provides moisture to the vegetation in and around the area.
- Rainwater harvesting improves the quality of groundwater by the process of natural filtration of fluorides, nitrates, and salts. This method of storing and utilizing water prevents soil erosion and flooding. Thus, it is an eco-friendly method.
- The stored water does not provide a breeding ground for mosquitoes and microorganisms, unlike the stagnant water in ponds and lakes.

River water

River is an important source of water. The source of a river could be a spring, a lake, a glacier, or surface run-offs. Rivers provide water to a large area as they travel long distances in the course of their flow. However, an excessive flow of water in rivers results in floods. River water is managed by building **dams**.

What are dams?

Dams are constructed across rivers to control the flow of water in them. The lock-gates in dams are used for checking and controlling this flow of water.



How are dams useful?

Dams provide a range of economic, environmental, and social benefits to human beings. Some of these are listed below.

Water supply: The water stored in dams is used for irrigation throughout the year, irrespective of the season. For example, the Indira Gandhi Canal originates in Bhakra dam and provides water to several areas in Rajasthan.

Hydroelectric power: Dams are also equipped with turbines and generators to produce hydroelectricity.

Flood control: Floods can be controlled by checking the flow of water in a river.

Recreation: Dams provide opportunities for water skiing, setting up of camping resorts, and boat launch facilities.

Waste management: Dams contribute to environmental protection through the retention of hazardous materials and detrimental sedimentation.

Disadvantages of dams

There are certain disadvantages associated with the construction of dams across rivers.

Environmental problems: The construction of dams across rivers leads to deforestation, which results in the loss of biodiversity. This creates a disturbance in the natural ecosystem.

Social problems: The construction of dams involves the building of large reservoirs. In some cases, constructing a reservoir may result in the flooding of nearby towns and villages.

A large number of people are displaced as a direct consequence of the construction of reservoirs. In such cases, the government rehabilitates the people of these areas, which in itself is a huge task.

Economic problems: The construction of dams requires huge amounts of monetary investments. A dam does not become profitable until it starts generating electricity.

As a result of all these problems, there is a strong opposition to the construction of large dams. The opposition to the construction of the **Tehri dam** over the river Ganga and the ***Narmada Bachao Andolan*** (a protest against the proposed increase in the height of the Sardar Sarovar Dam over the river Narmada) are examples of such opposition.

Collect information from newspapers, magazines, and news channels on dams that face the protest of people. Compare the reasons for these protests to learn more about the hazards created by dams.