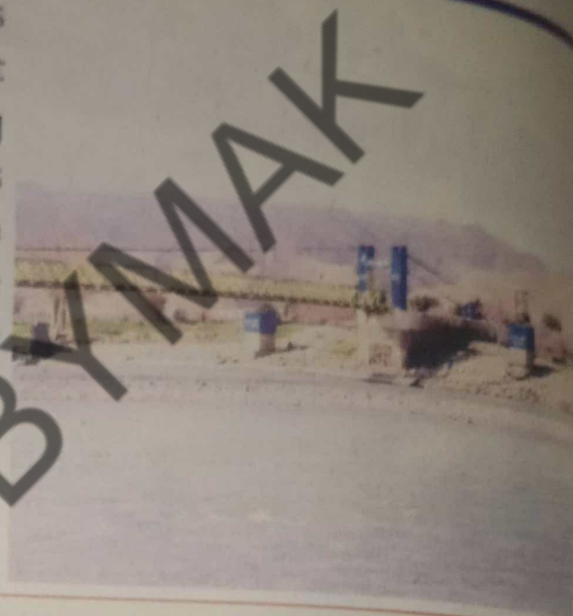


	Unit	Teaching (Periods)	Assessment (Periods)	Weightage %
15	Environmental Chemistry II: Water	10	2	16

Introduction

Water is the earth's most important liquid. It plays an important role in sustaining life on earth. Almost two thirds of the earth's surface is covered by water. Water is a transparent liquid, which makes up the streams, rivers, lakes, ponds and oceans on the earth. Water in oceans is mainly found in saline form and is not fit for drinking purposes. Besides this, the human body is also composed of 65-70% water by mass. The presence of water is necessary for performing various biological processes. Human blood plasma is composed of 92% of water.



Real world reading link

In the universe, earth is the only known planet that contains water. Earth has been called the blue planet. Approximately three percent of the planet's water is fresh water and it is our most precious resource but unfortunately we are contaminating and polluting this resource.

Water occurs in three different forms:

- Solid form as ice
- Liquid form as water
- Gaseous form as water vapour

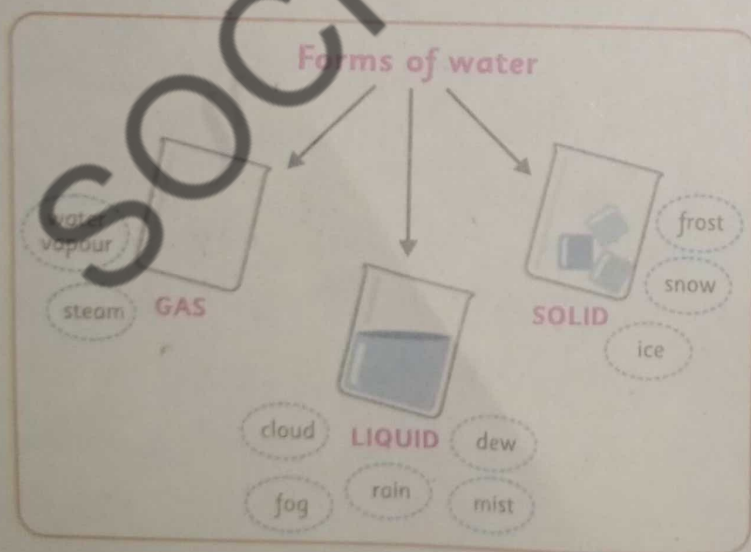


Fig.15.1 Forms of water

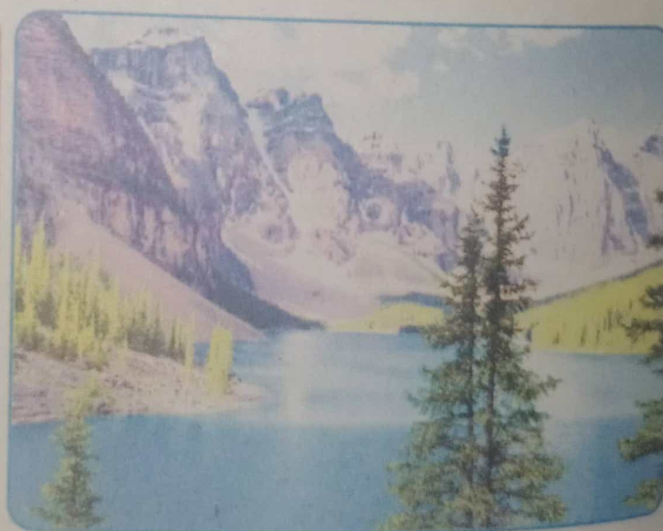


Fig.15.2 Sources of water

We use water in daily life for drinking, washing, cooking, irrigation etc. By using water, we pollute the water resource. Water is a universal solvent and occurs in nature in impure state. Therefore, water present in springs, streams, rivers, lakes and sea dissolve different minerals. These minerals may be in the form of chlorides, sulphates, nitrates, carbonates and bicarbonates of sodium, potassium, magnesium and calcium. Beside this, some man-made chemicals also get dissolve in water and make it harmful for human, animals, and plants. In this unit, you will study the composition, properties and importance of water. Beside this, you will also learn about soft and hard water, water pollutants and their effects on our lives. Various types of waterborne diseases will also be discussed in detail.

15.1 Water

Occurrence of Water

Water is one of the most abundant natural resources present on earth. It is a very good solvent for many substances. It has been estimated that total amount of water present on the earth is about 1.33 billion cubic kilometers. It covers about 70% of the earth's surface. The ocean contains more than 97% of world's water. The rest of the water is in the form of glaciers, ice caps, underground water and inland water.

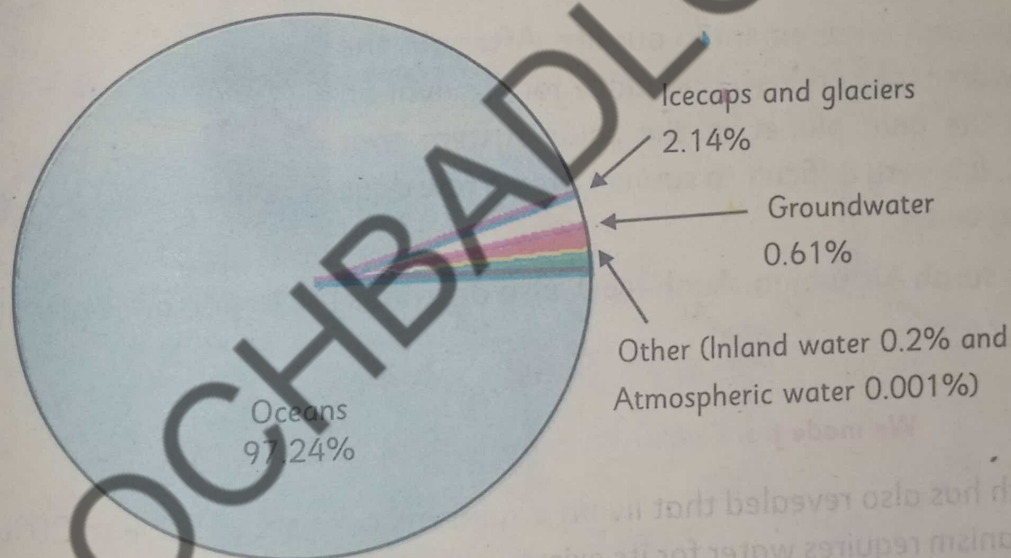


Fig.15.3 Occurrence of Water

The inland water includes rivers, lakes, canals, streams and soil moisture. Beside this, atmosphere also contains considerable quantity of water as water vapour. Although a huge amount of water is present on earth's surface, yet fresh water needed for human requirements is only 0.2% of the total. More than 97% of the total water is present in oceans, which is unfit for human consumption due to high concentration of dissolved salts. Another 2.14 % is present in the form of ice sheets and glaciers. On land most of the fresh water lies underground.

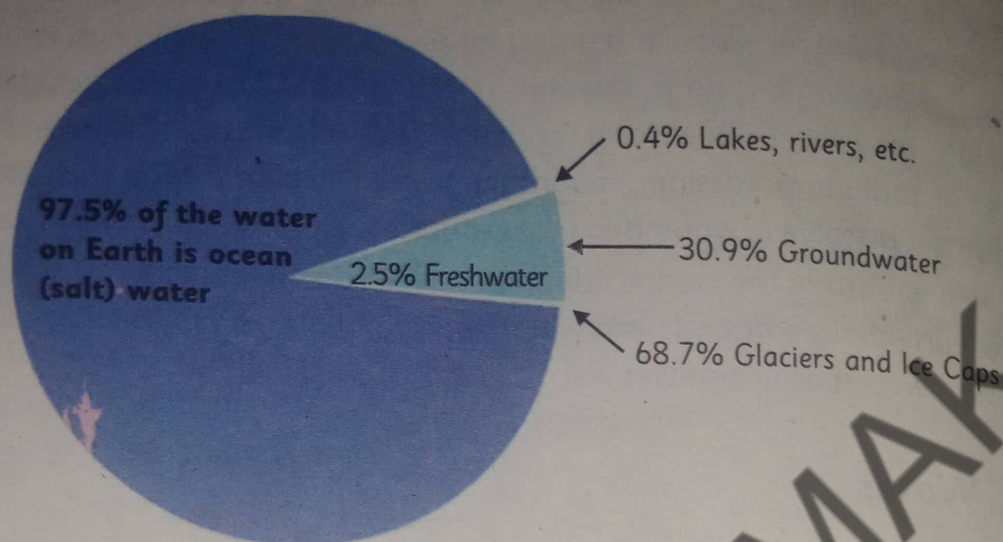


Fig.15.4 Distribution of Water on Earth

Tidbit

The heat required for converting a solid into a liquid or a liquid into vapours, without change of temperature is called latent heat.

Importance of Water

Water is an important requirement in our life. After air, the importance of water takes the second place for survival on earth. Earth is the only planet in the solar system that contains water. It is very difficult to survive even a few days without drinking water.



The Holy Quran surah Al-Anbiya, Ayah – 30, also describes the importance of water as

وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ

We made from water every living thing (Al-Anbiya-30)

Modern research has also revealed that living organisms consists of 50% to 80% water and every living organism requires water for its existence.

Our body cannot perform its functions without water. Our organs need water to perform different bodily functions. It is the water that lubricates our

food, keeps our organs moist and helps in digestion and movement of joints.

Reading Check

What are the different sources of water?

- Water is vital for maintaining life. The reactions, which take place in our body and keep us alive occur in the presence of water.
- Water regulates the temperature of earth.

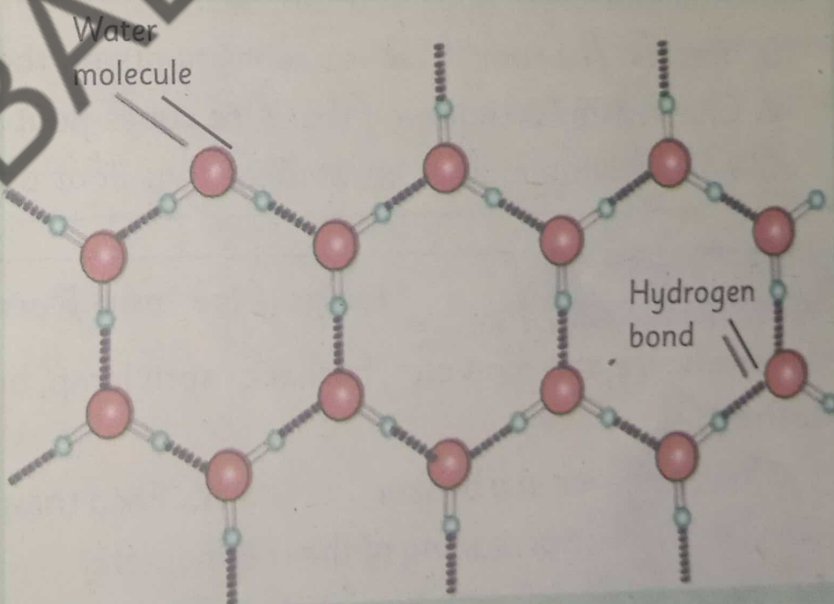
- Water serves as a medium for transportation, as ships and boats move on water.
- Water is a universal solvent, as many substances dissolve in it.
- Water enables our body to excrete waste during perspiration and urination. The kidneys and liver use it to help flush out these wastes from our body.
- Water is used in cooking and washing.
- Running water is used to generate electricity.
- It is used in the radiators of automobiles engines to cool it. It is also used in nuclear power plants, steel and iron industries, tanneries industries and other heavy industries.
- Water in lakes, rivers and oceans are used as a means of transportation.
- Fish and other aquatic animals and many plants live in water.
- Agriculture needs large amount of water, to cultivate fruits, vegetables, and other food.
- It is required for irrigating crops, as seeds cannot germinate without water.
- Many industries such as petroleum, fertilizer, dye and drugs industries require large quantities of water for various processes.

Tidbit

Unique quality of water – expansion of water when frozen

The density of most of the solids and liquids increases with decrease in temperature. However, water shows a unique behaviour in this regard. When water is cooled down below 4°C , its density decreases. At 0°C , the density of water becomes 0.91g/cm^3 .

Thus, ice is lighter and therefore floats on the surface of water. The expansion of ice is due to the formation of hexagonal structures. In these structures, six water molecules



Hexagonal structure of water molecules in ice

arrange themselves in the form of a ring having empty spaces. As a result, volume increases and density being inversely proportional to volume decreases. Therefore, water has a maximum density of 1g/cm^3 at 4°C . This unique property of water is called anomalous expansion of water.

Maintaining Water Quality

Water quality is defined on the basis of its physical, chemical, biological and radiological characteristics and its suitability for use. A healthy environment is one in which the water quality supports living organisms and protects their health. A single pollutant may give rise to different water quality problems.

A wide range of human activities affects water quality such as polluting of water by human faeces etc. If water quality is not maintained, not only environment will suffer but we will also face numerous problems like shortage of drinking water, intestinal diseases, irrigation problems, difficulties in fishing activities etc.

Water quality can be maintained by promoting awareness campaign among people about water quality. For example, people may be made aware not to put wastes and toxic substances into the running water, to maintain the pH and temperature of the water and do not disrupt the ecosystem.

Activity 15.1

Ice Floats on the Surface of Water

Materials: Ice, beaker

Method:

- i. Take water in beaker.
- ii. Add some ice cubes into a beaker.
- iii. You will see that these ice cubes float on the surface of water.
- iv. Give reason(s) that why these ice cubes float on the surface of water.
- v. Can you name other substances that float on the surface of water?

Activity 15.2

Heating Ice and Record the Temperature

Materials: Ice, thermometer, burner or spirit lamp, beaker

Method:

- i. Take some ice in a beaker.
- ii. Fix a thermometer in the beaker
- iii. Take the initial reading of the thermometer.
- iv. Heat the beaker with burner or spirit lamp.
- v. Observe the thermometer, does the temperature increase as you provide heat.
- vi. If no, give reason(s), that why temperature is not increasing.
- vii. Record your observation, when the temperature increases, Give reason(s) why it happen so.

15.1.1 Composition of Water

Water is a compound of hydrogen and oxygen. Before 1776, it was considered as an element. It was **Henry Cavendish** who proved experimentally that water is not an element but is a compound of hydrogen and oxygen. Composition of water can be determined by,

1. Volume

2. Mass

1. Composition of Water by Volume

Water contains two parts of hydrogen and one part of oxygen by volume. This ratio can be determined experimentally by the electrolysis of water in Hofmann's voltameter in the presence of an electrolyte. By passing electric current through acidified water, it produces two parts of hydrogen and one part of oxygen.

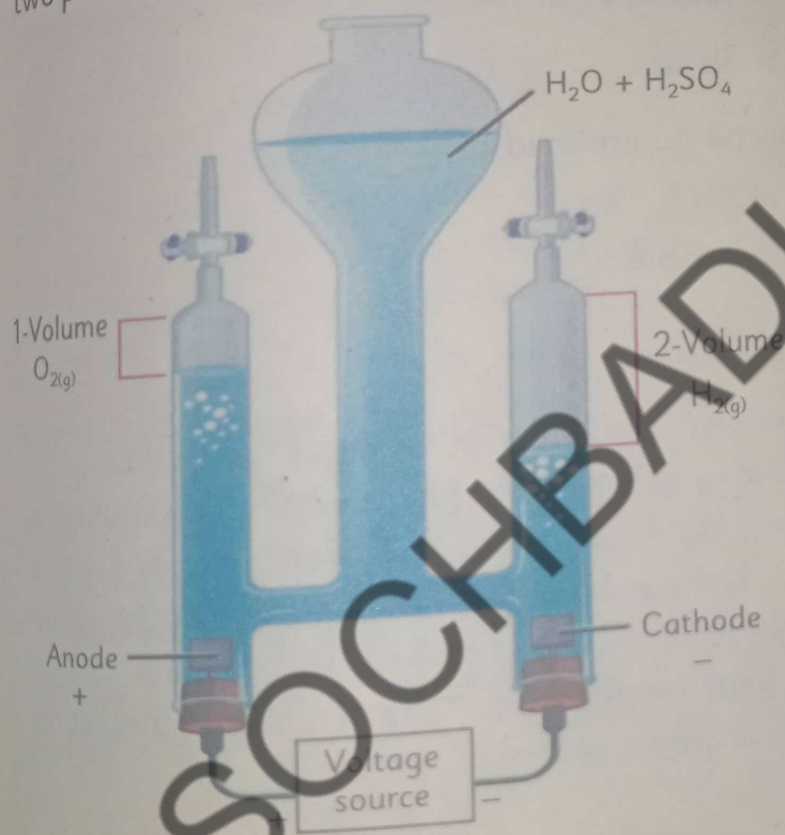
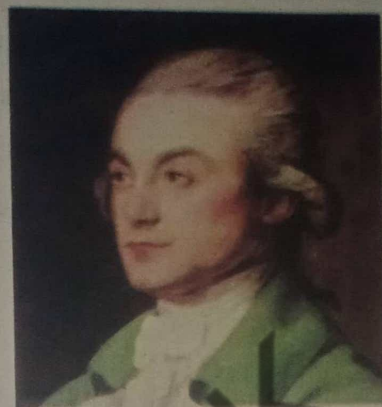


Fig. 15.6 Hofmann Voltameter

2. Composition of Water by Mass

Water is composed of one part of hydrogen to eight parts of oxygen by mass. Joseph Proust experimentally proved it that hydrogen and oxygen combine to form water in the ratio of 1:8 by mass. Since, the atomic mass of hydrogen is one, and that of oxygen is sixteen, so according to the formula H_2O

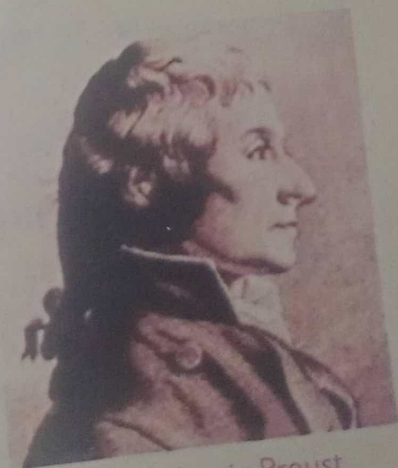


Henry Cavendish

Tidbit

Heat capacity

The specific heat capacity of a substance is the amount of heat required to raise the temperature of one gram of a substance through 1°C i.e. $14.5^\circ\text{C} - 15.5^\circ\text{C}$. For example, one gram of water requires 4.2 joules of heat to rise its temperature by one degree centigrade. This is much higher than the specific heat of many other common substances.



Joseph Louis Proust

The molecular formula of water = H_2O

Atomic mass of H = 1.01

Atomic mass of oxygen = 16

$$\begin{aligned}\text{Molecular mass of } \text{H}_2\text{O} &= 2\text{H} + \text{O} \\ &= 2(1) + 16 \\ &= 2 + 16 \\ &= 18\end{aligned}$$

$$\begin{aligned}\% \text{ age of Hydrogen} &= \frac{\text{Molecular mass of Hydrogen}}{\text{Molecular Mass of } \text{H}_2\text{O}} \times 100 \\ \frac{2}{18} \times 100 &= 11.11\end{aligned}$$

$$\begin{aligned}\% \text{ age of oxygen} &= \frac{\text{Atomic mass of Oxygen}}{\text{Molecular Mass of } \text{H}_2\text{O}} \times 100 \\ \frac{16}{18} \times 100 &= 88.88\end{aligned}$$

The ratio between hydrogen and oxygen can be determined as,

$$\begin{array}{rcl}\text{H} & : & \text{O} \\ 11.11 & : & 88.88 \\ 1 & : & 8\end{array}$$

Tidbit

Due to high specific heat, water undergoes temperature changes very slowly as compared to other substances. Water is able to absorb a lot of heat without a significant rise in the temperature. The vast amount of water on the earth's surface acts as a giant thermostat. It regulates the temperature of the earth. About 75% of the surface of the earth is covered with water, it takes longer for the oceans to heat than it does for the sand to be heated. Water's high specific heat helps to keep the climate in check and helps animals to regulate their body temperature more easily.

15.1.2 Properties of water

15.1.2.1 Physical properties of water

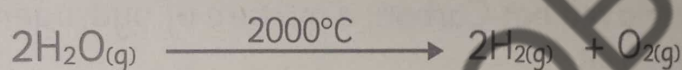
- Pure water is colourless, odourless and a tasteless liquid. The taste of the water is due to the dissolved salts and gases.
- Water exists in nature in all the three states i.e. solid (ice), liquid and gas (vapours).
- Freezing point of water is 0°C and boiling point is 100°C .
- Pure water is neutral to litmus. It does not change the colour of the litmus.

- Pure water has minimal electrical conductivity, but its conductivity increases as electrolyte (salt) dissolved in it.
- Water is a polar molecule.
- Pure water has density of 1.0g/cm^3 at 4°C .
- It has heat capacity of $4.18\text{J/g}^\circ\text{C}$
- Water conducts heat more easily than any other liquid.
- Water has high surface tension.
- The latent heat of fusion of water is 6kJ/mole , while the latent heat of vaporization of water is 41kJ/mole at 100°C .

Chemical properties of water

A. Thermal Stability of Water

Water is a thermally stable compound. This is because only one percent of its molecules decomposes into its components i.e. hydrogen (H_2) and oxygen (O_2) at about 2000°C .

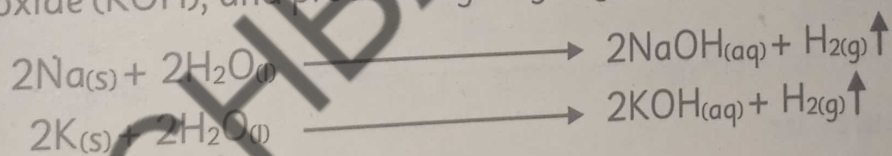


B. Reaction With Metals:

Water reacts with metals in a number of ways. The degree of reactivity of metals depends upon their position in the reactivity series.

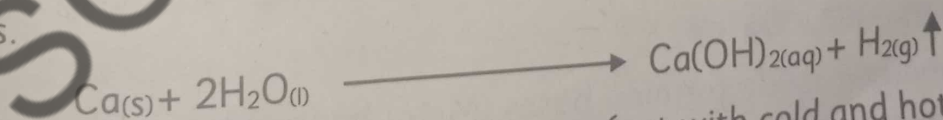
i. Reaction With Alkali Metals

Sodium (Na) and Potassium (K) react with cold water forming sodium hydroxide (NaOH), potassium hydroxide (KOH), and produce Hydrogen gas.

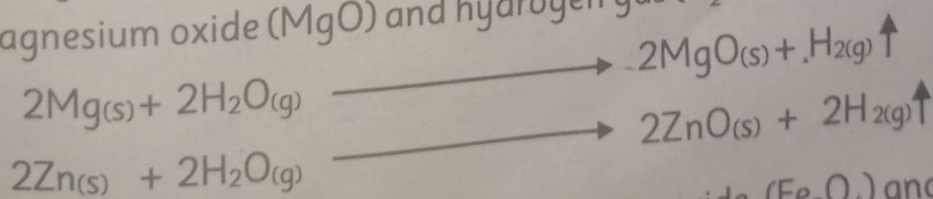


ii. Reaction With Alkaline Earth Metals

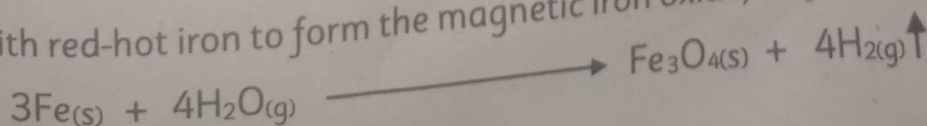
Calcium (Ca) react with water on heating to produce calcium hydroxide, $\text{Ca}(\text{OH})_2$ and liberates Hydrogen gas.



Zinc (Zn) and Magnesium (Mg) reacts with steam (not with cold and hot water) to form zinc oxide (ZnO) magnesium oxide (MgO) and hydrogen gas (H_2).



Steam react with red-hot iron to form the magnetic iron oxide, (Fe_3O_4) and hydrogen gas, (H_2).



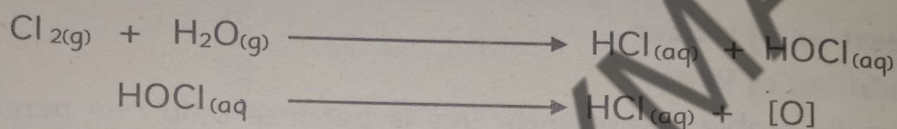
Other metals, for example Copper (Cu), Mercury (Hg), Gold (Au), and Platinum (Pt) do not react with water at ordinary conditions.

C. Reaction With Non-Metals

Water reacts with non-metals under different conditions to form a number of products.

i. Reaction With Chlorine

Chlorine gas reacts with water to produce hydrochloric acid (HCl) and hypochlorous acid (HOCl). The hypochlorous acid (HOCl) is unstable. It readily produces the atomic Oxygen (O), which can decolourise and kill the germs by oxidation. Wet chlorine acts as both a bleaching agent and a germicide.



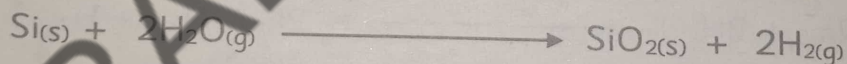
ii. Reaction With Carbon

When steam is passed over a red-hot Carbon, a mixture of hydrogen and Carbon monoxide, known as water gas is produced.



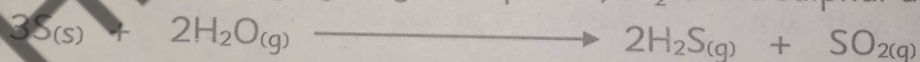
iii. Reaction With Silicon

Silicon at very high temperature reacts with steam to form silicon oxide commonly known as Silica (SiO₂) and hydrogen.



vi. Reaction with sulphur

Steam reacts with sulphur producing hydrogen sulphide, (H₂S) and sulphur dioxide gas, (SO₂).

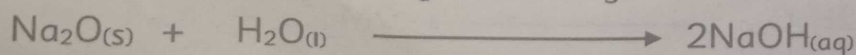


D. Reaction With Metallic Oxide

Water reacts with metallic oxide forming bases (Metal hydroxide).

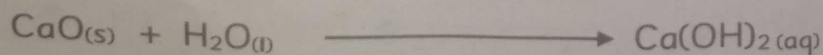
i. Reaction With Sodium oxide

Water reacts with sodium oxide forming sodium hydroxide (NaOH).



ii. Reaction With Calcium oxide

Water react with calcium oxide (quicklime) forming calcium hydroxide (slaked lime).

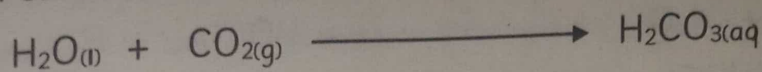


E. Reaction With Non-Metallic Oxide

Water reacts with non-metallic oxide to form acids.

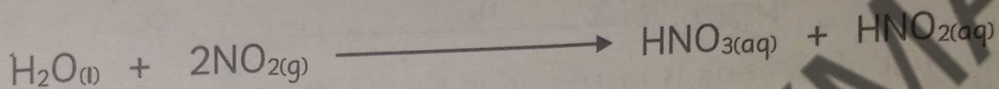
i. Reaction With Carbon Dioxide

Water reacts with carbon dioxide (CO_2) forming the carbonic acid (H_2CO_3).



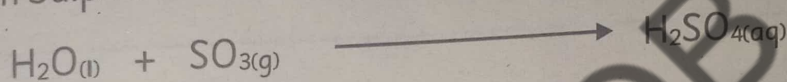
ii. Reaction With Nitrogen Peroxide

Water reacts with nitrogen peroxide (NO_2) to produce nitric acid (HNO_3) and nitrous acid (HNO_2).



iii. Reaction with Sulphur trioxide

Water reacts with Sulphur trioxide (SO_3) forming Sulphuric acid (H_2SO_4).

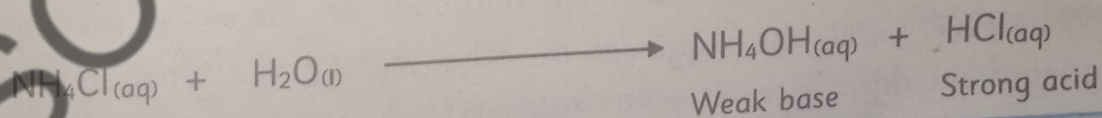
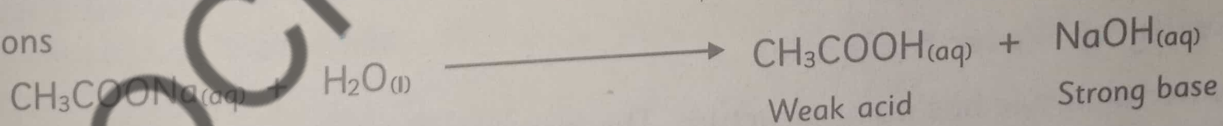


F. Hydrolysis Reaction

It is defined as the reaction in which H-OH bond of water molecule is broken down by the action of salt with water.

When a salt is added into water the solution becomes basic or acidic due to the hydrolysis reaction. In this reaction, dissolved salt react with water turning solution basic or acidic due to bond breaking of water.

Actually, the hydrolysis reaction is the reverse of Neutralization reaction. When salts of weak acid and strong base react with water, basic solution is formed and when salt of strong acid and weak base react with water acidic solution is formed. In this reaction water splits into H^+ and OH^- ions

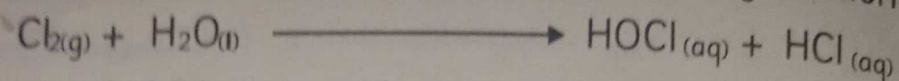


Society, Technology And Science

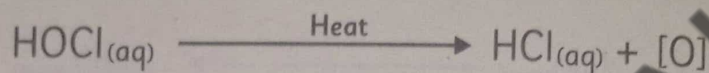
Chemistry Helps Maintain a Clean Swimming Pool

Chlorine is one of the most commonly used disinfectant for water disinfection. Chlorine can be applied for killing most microorganisms. Chemistry helps to maintain a clean swimming pool by killing bacteria and other microorganisms by using. Chlorine based disinfectants. It can be easily applied, measured and controlled. It is fairly persistent and

relatively cheap. Chlorine has a number of applications, such as the killing of pathogens in drinking water, swimming pool water and wastewater, for the disinfection of household areas and for textile bleaching etc. Chlorine itself does not kill when it is added into water, but it reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl).



The hypochlorous acid (HOCl) is unstable. It readily produces the atomic Oxygen (O), which can bleach the dyes and kill the germs by oxidation. Wet chlorine acts as both a bleaching agent and a germicide.



When the amount of chlorine is increased in the swimming pool water, it can cause eye irritation. The minimum concentration of chlorine in the swimming pool water is 0.5 mg/dm^3 and maximum level is 1.5 mg/dm^3 .

Water as Solvent

Water is the best-known solvent. It can dissolve more substances than any other solvent. Due to this fact, it is termed as a universal solvent for many inorganic and certain organic compounds. This property is very beneficial for us but sometime become a nuisance for us because mostly salts (pollutants) dissolve in water and is the cause of water pollution. This characteristic property of water that it dissolves more or less of everything is due to the following reasons.

- i. Polarity of water molecules
- ii. Hydrogen bonding in water
- iii. Dielectric Constant

i. Polarity of Water Molecules

The water molecule has polar structure. The hydrogen on one end of the water molecule is partially positive ($\text{H}^{+\delta}$) while the oxygen on the other end is partially negative ($\text{O}^{-\delta}$). It is due to the electronegativity difference between oxygen ($\text{O} = 3.5$) and hydrogen ($\text{H} = 2.1$) atoms.

Because of this polar structure, water is an excellent solvent for ionic solutes such as mineral salts, mineral acids and bases. When an ionic compound is added into water, oppositely charged ions are surrounded by water molecules. These oppositely charged ions of ionic compound are pulled by the water molecules and it becomes soluble in water. For example, NaCl, KCl, Na_2CO_3 , etc are soluble in water.

When an ionic compound such as sodium chloride (NaCl) is added to water. The sodium ion (Na^+) of NaCl is attracted towards the partial negative pole ($\text{O}^{-\delta}$) of water molecule while the

chloride ion (Cl^-) is attracted towards the partial positive pole ($\text{H}^{+\delta}$) of water molecule. The ionic bond break down in NaCl , which causes the sodium chloride to split in water and dissolves. The water molecules orient in such a way that the negative poles are towards the positive ions. Similarly, the positive poles of water molecules orient themselves around the negative ions. A hydration shell is formed around the ions, which prevents Na^+ and Cl^- from attracting each other.

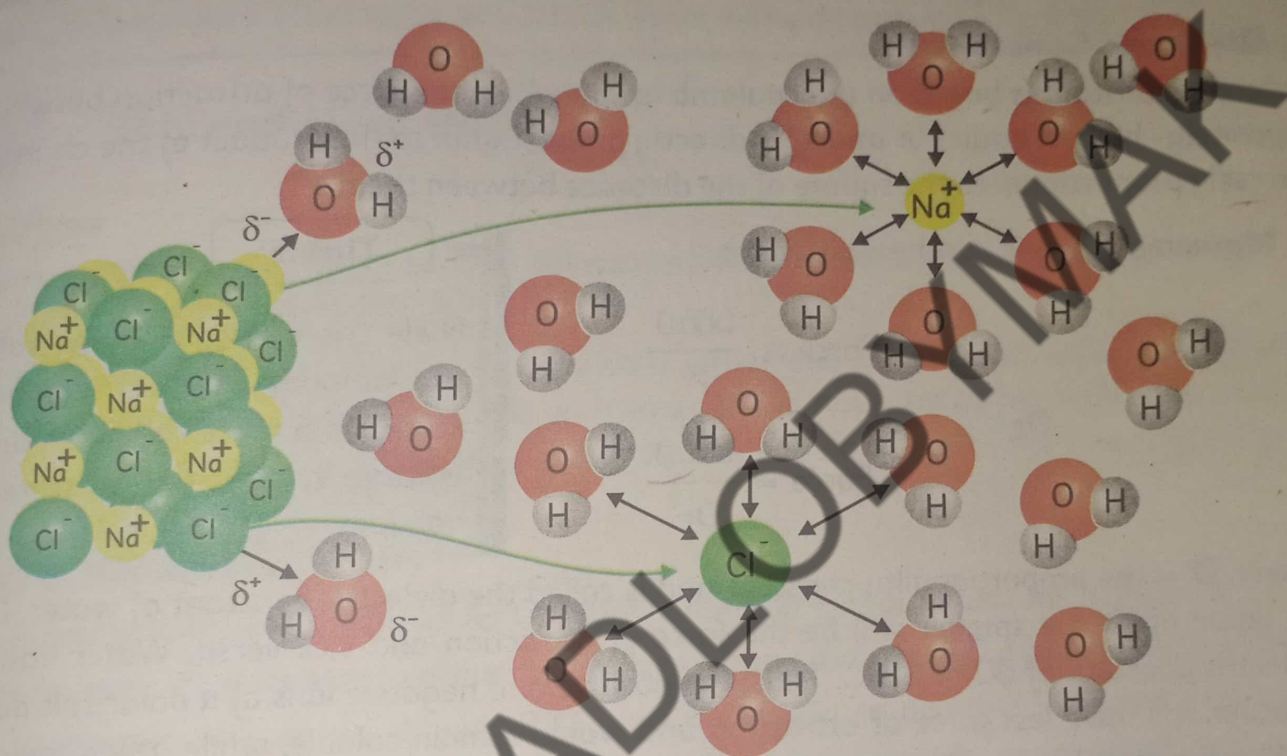


Fig. 15.7 Dissolving NaCl in Water

ii. Hydrogen Bonding in Water

Water molecule is composed of oxygen and hydrogen atoms. The hydrogen on one end of the water molecule is partially positive ($\text{H}^{+\delta}$) while the oxygen on the other end is partially negative ($\text{O}^{-\delta}$). Because of the presence of two nonbonding electrons (Lone pairs of electrons) on oxygen, water molecule forms four hydrogen bonds with other H_2O molecule. These H_2O molecules are arranged in a tetrahedral manner. Hydrogen bonding makes water unique.

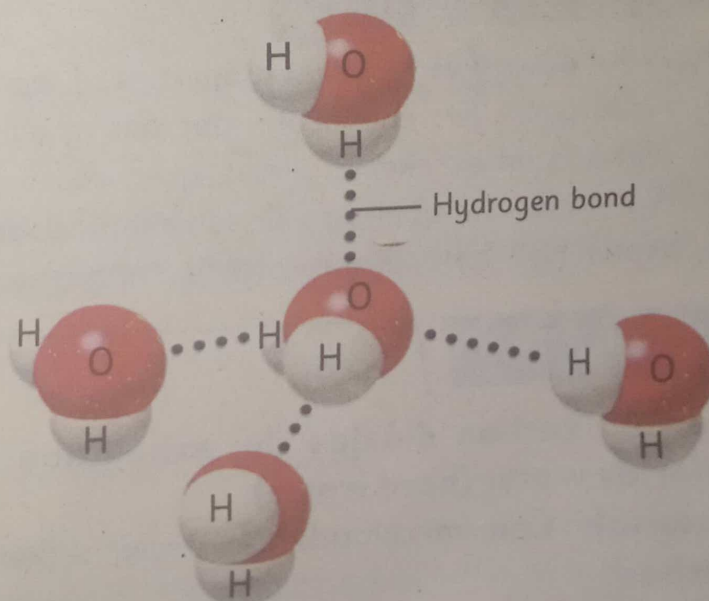


Fig. 15.8 Hydrogen Bond in Water

Covalent compounds, which have polar ends also form hydrogen bond with water. This behaviour enables water to dissolve some of the covalent compounds having hydroxyl group (OH) very easily. For example Sugar ($C_{12}H_{22}O_{11}$), Alcohol like methyl alcohol (CH_3OH), etc. will dissolve in water easily.

Besides this, a number of covalent substances such as alkanes, alkenes, benzene, ether etc. have no polar ends. These molecules are non-polar in nature, so they are insoluble in water.

iii. Dielectric Constant

Dielectric constant is based on the coulomb law in which the force of attraction between two oppositely charged bodies 'x' and 'y' is directly proportional to the product of the charges and inversely proportional to the square of the distance between them ' r^2 '.

Mathematically it can be written as,

$$\text{Force} \propto \frac{(x)(y)}{r^2}$$

Or

$$\text{Force} = \frac{(x)(y)}{Dr^2}$$

Tidbit

Dielectric constant is the ratio of the amount of electrical energy stored in a material by an applied voltage, relative to that stored in a vacuum.

Where 'D' is the proportionality constant and is called the dielectric constant of water. Greater the value of 'D' the smaller will be the force of attraction and vice versa. Water has a high dielectric constant of 80 at 18°C . Thus, the positive and negative ions of a polar salt dissolved in water will have less force of attraction and would remain soluble, while other liquids have small value of dielectric constant compared to water and therefore, these are not good solvents.

Self Assessment

1. Write down five physical properties of water.
2. Write down five chemical properties of water.
3. Water is an excellent solvent, give reasons.
4. Water has the ability to dissolve ionic substances explain with reason?
5. Water has the ability to dissolve non-ionic substances explain with reason?

Activity 15.3

Blowing carbon dioxide (by exhalation or breathing out) through Calcium Chloride water (hard water)

Materials: Calcium chloride salt, straw, beakers

Method:

- i. Take two beakers; add some water to both the beakers

- ii. Add some calcium chloride salt to one beaker.
- iii. Blow the carbon dioxide (CO_2) (by exhalation or breathing out) through both the beakers for five minutes by using the straw.
- iv. Observe both the beakers.
- v. In which beaker water turns milky? give reason(s).
- vi. Can you name other salts, which turn water milky on passing CO_2 gas?

15.2 Soft and Hard Water

Soft Water

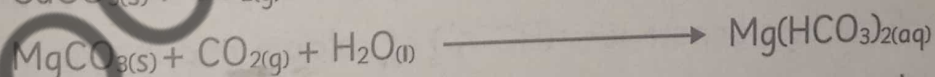
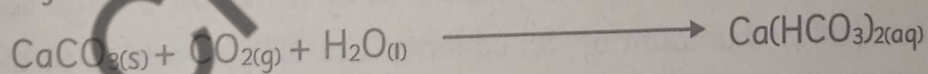
Soft water is that water, which easily produces good lather and does not scum with soap.

Hard Water

Hard water is that water, which produces little lather and forms scum with soap. In other words, the water which produces curds with soap. It will not form lather with soap and dirt cannot be removed readily. Thus, hard water wastes soap and affect the cleaning action of soap.

Causes of Hardness of Water

Water becomes hard when it dissolves Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) or Limestone (CaCO_3) from the soil. The rainwater on its way to ground, dissolves carbon dioxide (CO_2) from the atmosphere. Water which contains carbon dioxide (CO_2) has the ability to dissolve the small amount of calcium carbonate (CaCO_3) to form calcium bicarbonate. Similarly magnesium carbonate (MgCO_3) also react with water and carbon dioxide to form magnesium bicarbonate. The reactions are as follow:



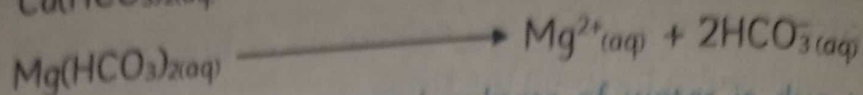
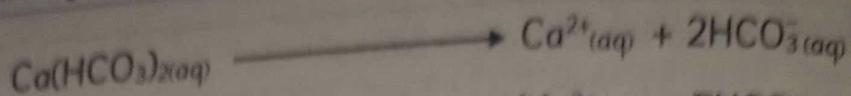
Water may also dissolve chlorides and sulphate of calcium, and magnesium. This underground water contains calcium ion and magnesium ion, which make the water hard.

15.2.1 Types of hardness of water

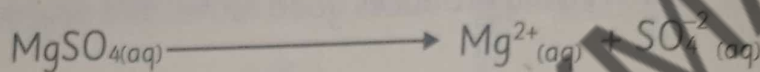
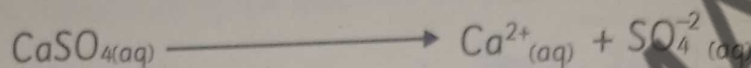
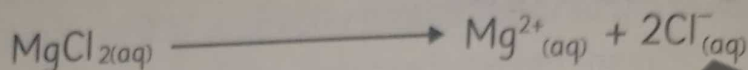
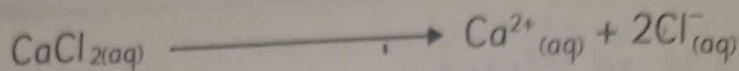
There are two types of hard water:

1. Temporary Hard Water
2. Permanent hard water

1. Temporary Hard Water: The temporary hardness of water is due to the dissolved Calcium bicarbonate and Magnesium bicarbonate. These salts are soluble in water and are present in the form of positive and negative ions as shown below.



2. Permanent Hardness: The permanent hardness of water is due to the presence of Chlorides (Cl^-) or Sulphate (SO_4^{2-}) of Calcium and Magnesium i.e. MgCl_2 , MgCO_3 , and CaSO_4 . These salts are soluble in water and produce the respective ions in water. Simple boiling of the water cannot decompose these salts.

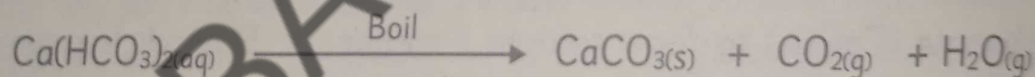


15.2.2 Methods of Removing Hardness

Methods of Removal of Temporary Hardness

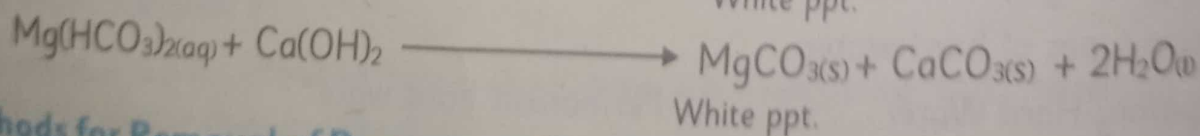
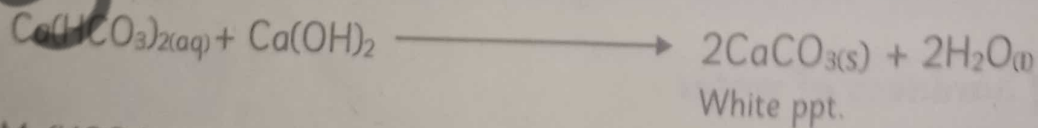
i. By Boiling the Temporary Hard Water

Temporary hardness of water can be easily removed by simple boiling the water. This hardness is caused by the presence of dissolved calcium bicarbonate, $\text{Ca}(\text{HCO}_3)_2$, which decomposes on heating. The calcium carbonate (CaCO_3) is formed. The calcium carbonate is insoluble and settles down as precipitate at the bottom.



ii. Clark's Method

This method is used to remove the temporary hardness of water on a large scale. This is a chemical method. A calculated amount of slaked lime, ($\text{Ca}(\text{OH})_2$) is added to the temporary hard water. The soluble bicarbonate ions (HCO_3^{-}) of calcium and magnesium present in temporary hard water are converted into their carbonate ions (CO_3^{2-}). The carbonates of calcium and magnesium are insoluble in water and settle down at the bottom.

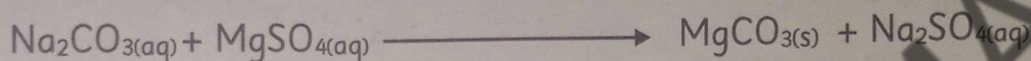
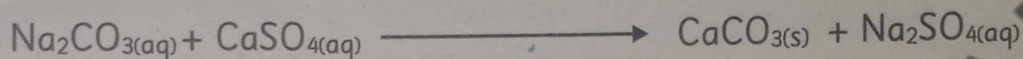
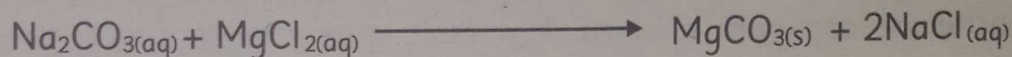
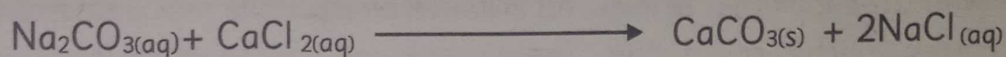


Methods for Removal of Permanent Hardness

Permanent hardness of water can only be removed by using chemicals, which convert soluble salts into insoluble salts on precipitation. The word **permanent** is misleading here because this hardness can be removed at the end.

i. By Using Washing Soda

The washing soda (Na_2CO_3) removes the permanent hardness of water. The washing soda reacts with the soluble calcium and magnesium chloride and sulphate and converts them into insoluble calcium and magnesium carbonate respectively.



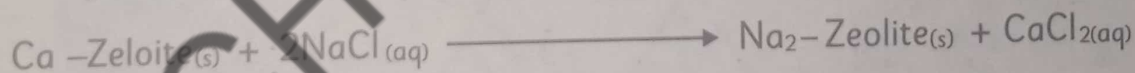
ii. Ion Exchange Method

Zeolite is an ion-exchange resin which is integral part in the water treatment process in both consumer and industrial settings. Zeolite is naturally occurring sodium aluminum silicates. It can also be prepared artificially. This resin is commonly known as Sodium Zeolite.

When the hard water is passed through the resin, the Sodium ions will go into the solution while the unwanted Calcium and Magnesium ions take their place in the resin.



When the $\text{Na}_2\text{-Zeolite}$ is used up and becomes inactive then it can be regenerated by treating it with a strong solution of common salt (NaCl).



Tidbit

Sodium Zeolite

Sodium Zeolite is a white powdery substance with a cubic crystal structure. Sodium Zeolite is a mineral, the general formula of sodium zeolite is $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x \text{SiO}_2 \cdot y\text{H}_2\text{O}$. Sodium zeolite acts as an ion exchange medium. Zeolites are capable of exchanging their Na^+ ions with hardness producing ions like Ca^{2+} and Mg^{2+} present in water.

In addition to water softening, sodium zeolite has been used as a catalyst in the cracking of petroleum, as a drying agent, and as an absorbent.

Hard Water Hampers the Cleaning Action of Soap

Soaps are the sodium salts of the fatty acids. When soap is added to hard water, it ionizes into sodium ion and stearate ion. The Ca^{+2} and Mg^{+2} ions are present in hard water. The ions react with the soap (stearate ion) and produce an insoluble precipitate of calcium and magnesium stearates, which is called scum. These scums hamper the lather formation in water. The cleaning action of soap is also affected. As a result, large amount of soap is wasted.

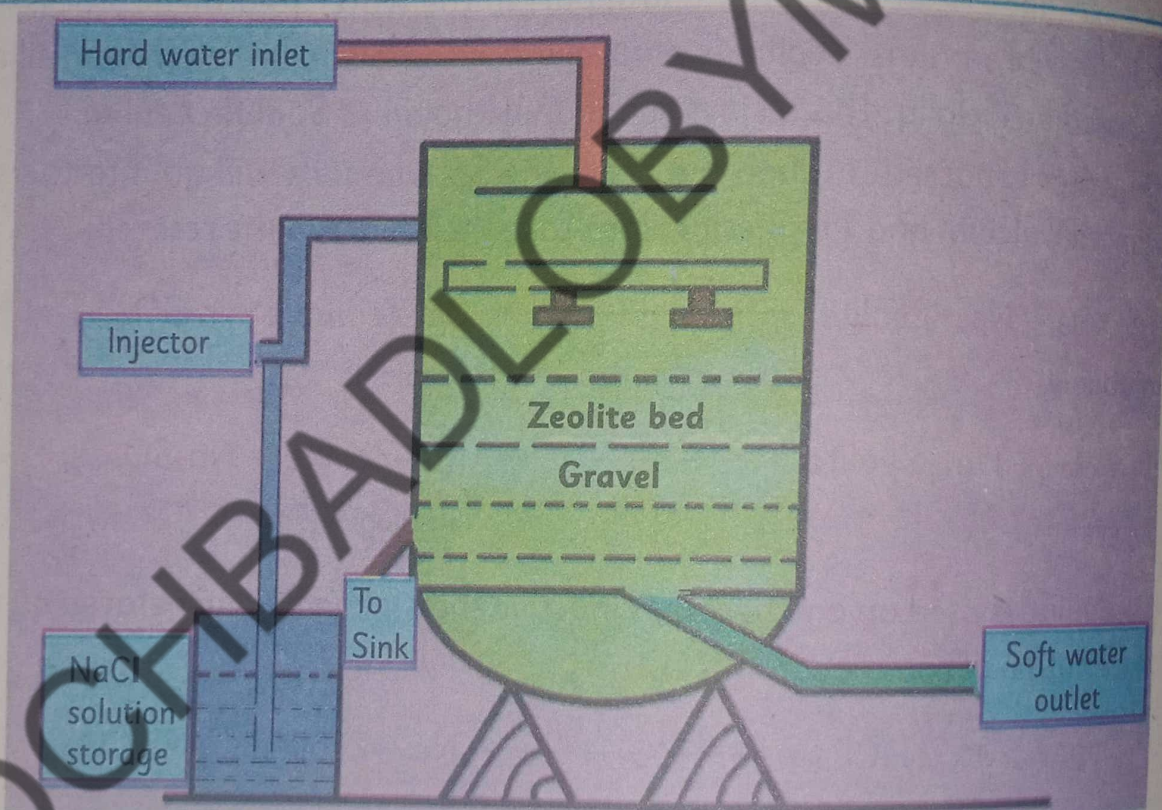
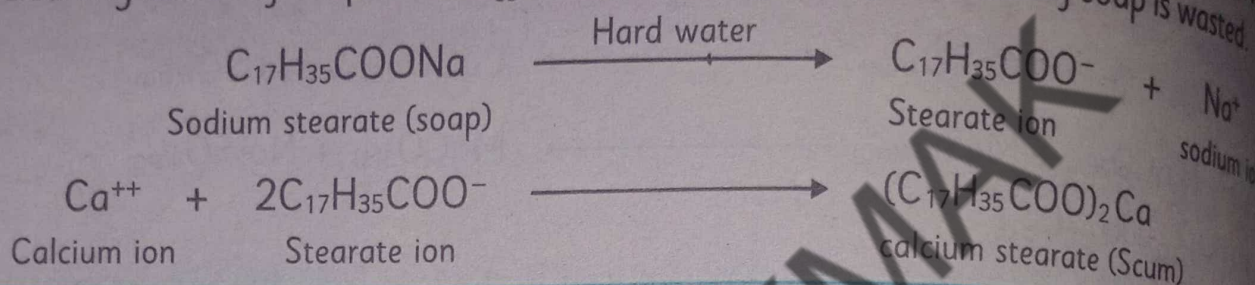


Fig. 15.9 Ion Exchange Method

15.2.3 Disadvantages of Hard Water

The following are the disadvantages of hard water.

- Hard water consumes large amount of soap in washing process.
- Hard water is unfit to use in steam engines and boilers. When the hard water is used in the boiler, calcium and magnesium salts settle down at the bottom as hard insulating scale. As a result, more fuel is consumed in producing

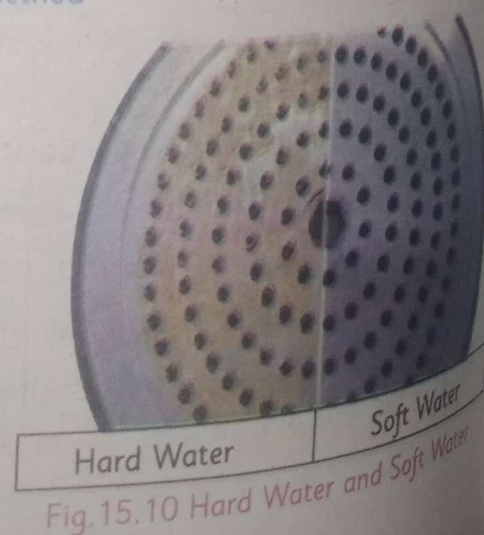


Fig. 15.10 Hard Water and Soft Water

steam. If these scales are not removed, they block the tubes, which lead to the engines. These make a constant threat to the explosion of boiler. This deposition of scales inside the boiler causes overheating and reduces the life of boiler.

- Use of hard water for drinking purposes for a long time causes dysentery, intestinal and stomach diseases. If magnesium sulphate is present in the hard water, it weakens the stomach function.

Self Assessment

1. How temporary hardness of water can be removed?
2. How permanent hardness of water can be removed?
3. Which salts are the cause of temporary hardness of water?
4. Which salts are the cause of permanent hardness of water?
5. What is sodium zeolite? How it makes the water soft?
6. Write down the disadvantages of hard water.

Activity 15.4

Testing of Water by Adding Potash Alum

Materials: potash alum, beaker

Method:

- i. Take a beaker; add some water into beaker.
- ii. Add some potash alum to it and shake it for some time.
- iii. Leave it undisturbed for 10 minutes.
- iv. Observe the water in the beaker. Do you observe some changes in water of the beaker?
- v. If yes, what did you observe and why? Give reason.

Interesting facts

Measures of water hardness

Milligrams of soluble salts of Mg and Ca per dm^3	Level of Hardness
0 to 60 mg/dm^3	Soft
61 to 120 mg/dm^3	Moderately Hard
121 to 180 mg/dm^3	Hard
More than 180 mg/dm^3	Very Hard

Pollution is defined as the introduction of the substances which are undesirable and cause the contamination of the environment. **Water pollution occurs when undesirable substances are introduced into natural water.** Water is considered as polluted and unfit for drinking when it is contaminated with substances (pollutants) which are harmful for human beings and other living organisms. About 70% of the earth's surface is covered by water. However, the reservoirs of fresh and useable water are very limited. The human activities are constantly destroying the fresh water resources.

Water is an excellent solvent and can dissolve vast variety of substances. Therefore, natural water, when it flows or seeps through the surface of the earth, dissolves minerals including salts and other substances. Despite these mineral impurities, water of most lakes, rivers, springs and wells is considered fit for drinking and other domestic uses. The substances which pollute water can be chemical or biological in nature. Common pollutants include human or animal waste, disease-producing organisms, toxic metals such as lead or mercury, agricultural chemicals such as pesticides, herbicides or fertilizers, acid rain and high-temperature water discharge from power plants. Pollutants in water are dangerous for living consumption and unfit for drinking purposes.

The substances that cause water pollution are called pollutants. These pollutants are dissolved in water from the soil, atmosphere, fields, factories, farmhouses, volcanoes, storms, algae blooms and homes etc. According to the reports of W.H.O. (World Health Organization), about 80% of the diseases are caused due to the polluted water in developing countries.

The major sources of water pollutants are

- i. Industrial wastes,
- ii. Household wastes,
- iii. Agricultural waste and
- iv. Animal waste

15.3.1 Industrial Waste

As the population increases their demand for food, clothes, paper, plastics etc also increases. In order to meet these demands industrial units are established to produce the desired substances on commercial scale.



Fig.15.11 Water Pollution



Fig.15.12 Industrial Discharge into River

These industrial units unfortunately discharge their wastes such as hot water, chemicals and solids materials either to open grounds or to running water. These are absorbed by lower forms of life and passed into the food chain, causing deaths, birth defects and mental problems. These substances are called industrial wastes.

- Most of the industries have been started without proper planning and waste treatment plants. They just dispose off untreated toxic waste into nearby drains, canals or rivers. Industries produce lots of wastes. These wastes are highly toxic due to the presence of compounds like Mercury, Cadmium, Lead, Chromium, Arsenic, etc, acids such as hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3) etc, oils, grease, dyes and may also contain some gases in dissolved form.
- Water used in industries as a coolant or for cleaning purposes dissolves all the chemicals and detergents and causes water pollution when discharge from industries. These industrial wastes also pollute groundwater. The compounds which are discharged from industries gets into the body through edible substances and cause different diseases.
- Radioactive wastes that may leak from nuclear power stations also create many problems to the living organisms.

Reading Check

Differentiate between waste and pollutant.

Heated Water

Some industries and power stations use water for cooling purposes. When this hot water discharges into the rivers, it may destroy the fish and other aquatic life, if the temperature of this hot water is higher than 30°C .

Untreated Water

In areas where there are no sewage water treatment plants. The sewage water goes into the rivers and other water sources. Sewage water consists of bacteria, germs and viruses. When this water is used for drinking purposes, they cause Typhoid, Cholera, Hepatitis, Pneumonia and dysentery problems.



Fig.15.13 Industrial Wastes in River Water

Tidbit

Biological Oxygen Demand (BOD) and Chemical oxygen demand (COD) are water quality tests, which determine the quality of water.

Biological Oxygen Demand (BOD) is also known as biochemical oxygen demand, is a procedure that measures the dissolved oxygen (DO) consumed by micro-organisms during the decomposition of organic matter.

Chemical Oxygen Demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemical such as ammonia and nitrite.

15.3.2 Household Wastes

Household wastes are produced inside the houses during day-to-day activities like using soaps and detergents for cleaning purposes etc. When this household water enters the water bodies such as streams, canals, rivers, lakes etc or groundwater it causes water pollution. These household wastes remain in water in dissolved form or in suspended form for long time and affect the aquatic life.

Household wastes can be broadly divided into two categories.

- i. Waste water
- ii. Solid wastes

i. Waste water

It consists of water used in kitchens, washrooms and cleaning floors etc. This water is discharged into the running water. These detergents and other chemicals like medicines, acids, bleaches, dyes, waxes, hair colors etc affect the quality of water and affect the aquatic life. Flushed water mostly contain pathogens such as bacteria, viruses and protozoans. In our country drinking water, supply lines and open sewage drains in the streets are laid side by side. As a result, water is frequently contaminated when pipes erode.



Fig.15.14 Household Waste

Tidbit

The major disadvantage of detergent over soap is that it is non-biodegradable. Microorganisms like bacteria etc cannot decompose detergent, while these microorganisms can easily decompose soap.

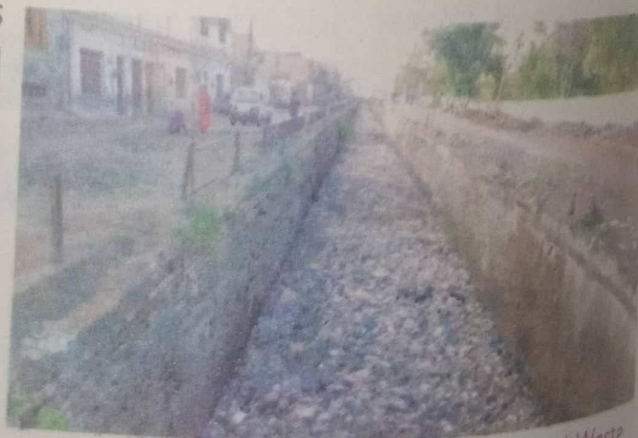


Fig.15.15 Untreated Sewage and Solid Waste

ii. Solid waste
Solid waste is also called urban waste or domestic waste. It is either in solid or semisolid form. It contains food, newspapers, glass bottles, cans, metals, etc. Today, many people dump their garbage into streams, lakes, rivers, and seas. When rainwater or other forms of water come in contact with these materials (chemicals), it removes or extracts chemicals from these solid wastes (materials). This process is called leaching and the resulting mixture is called leachate. Leachate either seeps into the soil and pollutes underground water or finds its way to rivers and streams through rainwater.

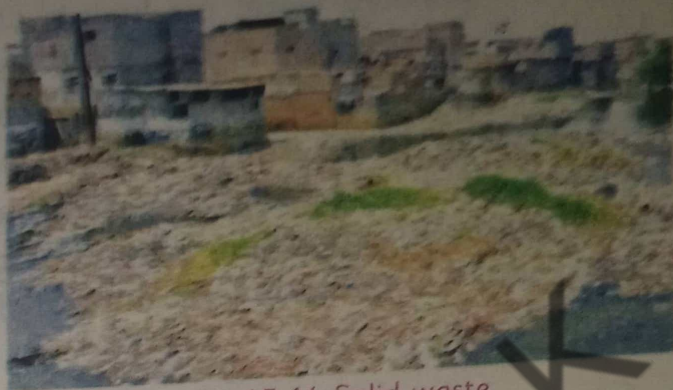


Fig.15.16 Solid waste

15.3.2 Agricultural Wastes

Agricultural wastes are wastes produced as result of various agricultural activities. Agricultural wastes include both natural (organic) and synthetic wastes. Natural (organic) wastes include manure and other wastes from farming, harvesting, poultry and slaughter houses etc. Whereas, synthetic wastes consists of fertilizers in run-off water from fields, pesticides, insecticides and herbicides that enter into water, air or soils and salt and silt drained from fields.

15.3.3 Animal Wastes

Animal wastes also pollute water. In many areas of our cities and villages, animals are raised in residential areas. The animal's excreta are usually discharged into the canals and rivers, where it pollutes the water with microorganisms.

Self Assessment

1. Name the major sources of water pollution.
2. What is an industrial waste?
3. How fertilizers cause pollution?
4. Discuss how the household waste pollutes water.
5. Agricultural waste and animal wastes cause water pollution, give reasons.

15.4 Waterborne Diseases

Water is the source of life. However, modern research showed that as much as water could be a source of life; it could also bring much threat to life, if we drink polluted or contaminated water. The diseases that spread because of drinking polluted water or eating those foods that are



Fig.15.17 Drinking Polluted Water

prepared in polluted water are known as waterborne diseases. Waterborne diseases are bacterial, parasitic or viral diseases. These diseases directly transmit, when contaminated drinking water is consumed or food prepared in contaminated water is eaten. Waterborne diseases are a major cause of mortality worldwide. According to the World Health Organization, diarrheal diseases are responsible for the deaths of 1.8 million people every year. Some examples of these diseases are given below.

1. Bacterial Infections

i. Cholera

Cholera is a waterborne disease that affects the intestine. Its symptoms usually are watery diarrhea and vomiting which can lead to dehydration and electrolytic imbalance.

ii. Dysentery

It is one of the most common waterborne diseases. This is the large intestinal disease, causing abdominal cramps, anal pain and bloody stool.

iii. Typhoid Fever

Another example of waterborne diseases is typhoid fever. This is caused by a bacterium, which enters the bloodstream, making the person infected with typhoid fever.

2. Viral Infections

i. Hepatitis A and E

These two types of the hepatitis viruses are usually found in unsanitary surroundings and contaminated water. These viruses attack the liver and cause jaundice, hepatitis etc. They can even cause liver failure.

ii. Polio

The polio is a viral disease. The polio virus usually enters the environment through the faeces of someone who is infected. In areas with poor sanitation, this virus easily spreads, through contaminated food, water etc. Sometimes, it can transmit through a sneeze or a cough, as the virus lives in the throat and intestines.

Reading Check

Define Waterborne diseases.

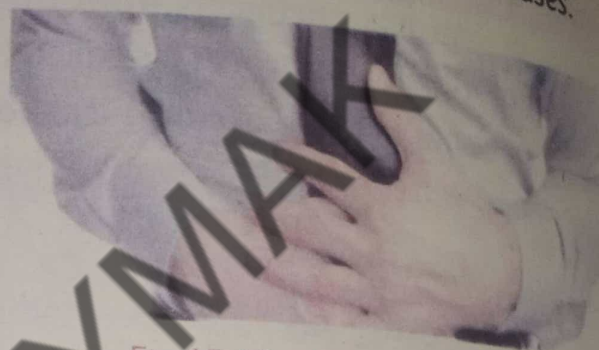


Fig.15.18 Abdominal Cramps



Fig.15.19 Typhoid Fever



Fig.15.20 A Child With Polio

3. Protozoal Infections

Protozoal infections include Amoebiasis. In this infection, amoeba enters through unsanitary food or contaminated water. The person faces serious gastrointestinal illness.

4. Parasitic Infections

Guinea worm and pinworm infection are common parasitic infection. It is mainly found in children. They spread by swallowing the eggs of these worms through drinking contaminated water or eating spoiled food. They cause ulcers, fever, vomiting, nausea etc.

5. Arsenicosis and Fluorosis

Drinking water with Arsenic and fluoride minerals has serious effects on health.

Fluorosis is a disease caused by drinking water with excess fluoride. It damages the bones and teeth.

Arsenicosis is a disease caused by drinking water with high levels of arsenic. It is also known as arsenic poisoning. The symptoms of arsenic poisoning are excess of saliva, vomiting, nausea, blood in urine etc. The WHO recommended limit of arsenic in drinking water is 0.01 mg/dm^3 .



Fig. 15.21 Dental Fluorosis



Fig. 15.22 Arsenicosis

Society, Technology And Science

Treatment is Essential for Water to be Drinkable

Water, which is prepared for special purposes is called treated water e.g. distilled water, drinking water and chlorinated water of swimming pools. Water is passed through different processes in order to remove impurities from water and make it suitable for drinking.

First, water is stored in settling basin, treated with calcium hydroxide and aluminum sulphate to remove suspended impurities and dissolved solids. It is then filtered through sand and gravel bed to remove remaining suspended particles. After this water is passed through charcoal to remove colour and odour. At last stage, chlorine is passed from water to kill microorganism (germs) such as bacteria etc. Now this water is suitable for drinking and other purposes.

Water treatment process improves the quality of water. In the treatment process, the removal of suspended and dissolved solids and killing of the pathogens, makes the water clean and safer for drinking. If we drink the untreated or contaminated water, there is a great risk of being seriously ill. So it is always advisable to drink treated water.

1. Infectious Disease

Water pollution is the major cause of infectious diseases in human beings. These diseases include typhoid, cholera, dysentery, amoebiasis, ascariasis and hepatitis etc.

2. Nutrient Pollution

Nutrient pollution is a form of water pollution. In this process, large amount of nutrients such as nitrogen, phosphorus, nitrates etc become part of water as a runoff from agricultural fields or weathering of rocks. This enrichment of nutrients in water bodies is called eutrophication. These excessive amounts of nutrients create problems such as excessive growth of algae, decrease in dissolved oxygen in water etc. This, in turn, can kill fish, crabs, oysters, and other aquatic animals.

3. Chemical Contamination

Some of the major effects of chemical contamination are as under.

- Pesticides affect and damage the nervous system, liver, reproductive system, endocrine glands and DNA etc.
- Oil and petrochemical can alter the ecology of aquatic habitats and the physiology of marine organisms. In human beings, it causes gastro-intestinal irritation, liver and kidney damage and nervous system effects.
- Mercury and its compounds are used in many industries. It finds its way into the water bodies primarily through air pollution and industrial wastes. Mercury gets into the body through food especially seafood. In children, it causes brain damage, learning defects and incomplete mental development. In adults, mercury causes Parkinson's disease, Alzheimer's disease etc.

4. Thermal Water Pollution

Hot water from industrial processes is directly allowed to become the part of the environment.

This hot water affects the aquatic life in two ways:

- The hot water decrease the solubility of oxygen as a result aquatic organisms will die due to the shortage of oxygen.
- Many aquatic animals especially young cannot survive in water above 30°C and will die.



Fig. 15.23 Canals Water

Key Points

- Water covers two third of the earth's surface.
- Water is a transparent liquid, which makes up the streams, rivers, lakes, ponds and oceans on the earth.
- Human blood plasma is composed of 92% of water.
- Water occurs in three different forms, solid, liquid and gas.
- Water is a universal solvent.
- Water is one of the most abundant natural resources present on earth.
- 97% of the total water is present in oceans, which are unfit for human consumption due to high concentration of dissolved salts.
- 2.14 % is present in the form of ice sheets and glaciers.
- Fresh water needed for human requirements is only 0.2% of the total.
- The Holy Quran in Al-Anbiya Ayah – 30, describes the importance of water as "And we made from water every living thing".
- Water quality can be defined on the basis of its physical, chemical, biological, and radiological characteristics of water.
- Pure water is colourless, odourless and a tasteless liquid.
- The latent heat of fusion of water is 6kJ/mole, while the latent heat of vaporization of water is 41kJ/mole at 100°C.
- Soft water is that water which produces easily, good lather and does not form scum with soap.
- Hard water is that water which produces little lather and form scum with soap.
- There are two types of hard water; temporary hard water and permanent hard water.
- Temporary hardness of water can be removed either by boiling or by Clark's method.
- Waterborne diseases are those diseases that spread because of drinking polluted water or eating those foods that are prepared in polluted water.
- Mercury accumulates in the blood, liver, kidneys and brain tissues. In young children it causes brain damage, learning defects etc.
- Many aquatic animals especially young ones cannot survive in water above 30°C and will die.

Exercise

A. Choose the Correct Option.

- Water has the ability to dissolve non compounds due to
 - Ionic forces
 - Dipole-dipole forces
 - Ionic-dipole forces
 - Hydrogen bonding
- All salts cause the water become hard except
 - Calcium Chloride
 - Calcium Bicarbonate
 - Magnesium Sulphahte
 - Sodium Chloride
- The salt which causes temporary hardness in water is
 - Magnesium Sulphahte
 - Calcium Chloride
 - Magnesium Chloride
 - Calcium Bicarbonate
- Chlorine acts as bleaching agent in the presence of
 - HCl
 - H_2O
 - NaOH
 - HNO_3
- Permanent hardness of water is removed by adding
 - Washing Soda
 - Soda lime
 - Caustic Soda
 - Baking Soda
- Most of the aquatic animals cannot survive in water above,
 - $20^{\circ}C$
 - $25^{\circ}C$
 - $30^{\circ}C$
 - $35^{\circ}C$
- The destiny of water maximum at
 - $-40^{\circ}C$
 - $40^{\circ}C$
 - $-4^{\circ}C$
 - $4^{\circ}C$
- The disease which cause liver infection
 - Hepatitis
 - Cholera
 - Typhoid
 - Dysentery
- All are waterborne diseases except
 - Hepatitis
 - Malaria
 - Typhoid
 - Dysentery
- Water gas is a mixture of
 - CO and H_2
 - C and H_2
 - CO and H_2O
 - C and H_2O

B. Short questions.

- Identify the factors which are responsible for dissolving polar substances in water?
- Explain why it is advisable to drink boiled water.
- Why ice floats on the surface of water?
- Explain the importance of water and its quality?
- What is eutrophication? How does it pollute water?
- How chemistry helps to maintain clean swimming pools?

7. Make the distinction between soft and hard water.
8. Why water is universal solvent?
9. Give some of the disadvantages of the detergents?
10. Identify the different toxic substances in household wastes.

C. Long questions.

1. a). Enlist the main sources of water?
b). How would you categorize physical properties of water?
c). Predict the product of reaction, (i). K (ii). Cl_2 (iii). CaO (iv). CH_3COONa (v). C, with water.
2. Water is an excellent solvent. Explain how this property is beneficial for life but sometimes harmful for us.
3. a). Classify temporary hard and permanent hard water.
b). What methods could be adopted to remove the temporary hardness of water.
c). What methods could be adopted to remove the permanent hardness of water.
4. a). Why water is important for us?
b). Write the disadvantages of hard water?
c). Enlist the advantages of wastewater treatment.
5. a). How would you evaluate the effects of water pollution?
b). Explain how industrial wastes pollute environment.
c). Support the view that domestic wastes cause pollution.
d). How would you relate the agricultural wastes and water pollution.

Project

1. Prepare a report on the waterborne diseases in our country.
2. Design some ways to eliminate the waterborne diseases from our country.
3. Enlist some ways of preventing water contamination.