

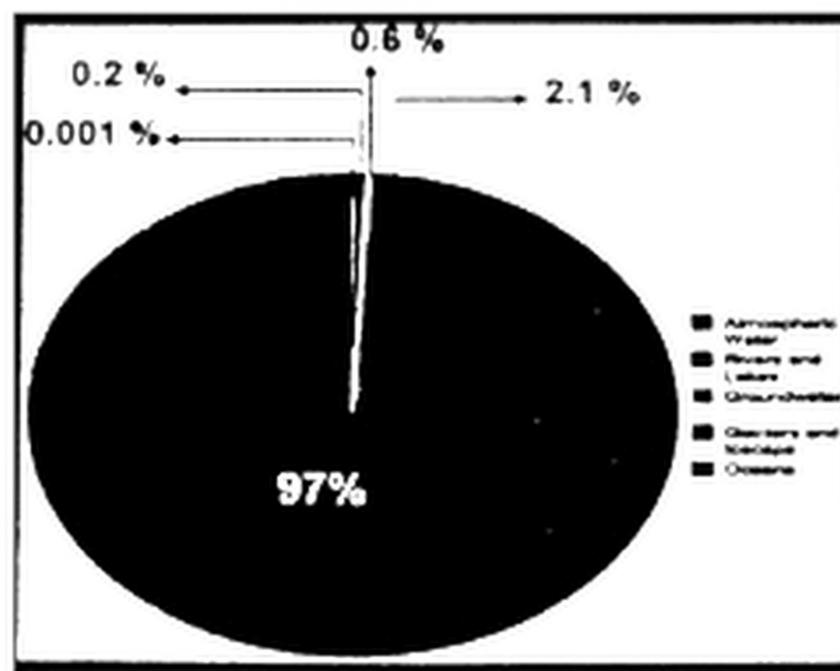
# Chapter 15

## Environmental Chemistry – II:

### Water

**Q1. Describe the occurrence of water?****Ans: Occurrence of water:**

Water is one of the most important substances on Earth. It is present in enormous quantities on earth. It has been estimated that total amount of water present on earth is about 1.33 billion cubic kilometers which nearly covers 71% of earth's crust.



**Distribution of water on Earth**

Although, an enormous amount of water is found on earth, but the fresh water available to man is only 0.2% of the total.

Sodium Chloride is the most abundant salt in sea water. It is present upto 3.4% in it. This water is unfit for human use.

**Q2. Highlight the importance of water in the environment including industry.****Ans: Importance of water:**

You can live without food for 3 to 4 weeks, but cannot survive without water for more than 3 to 4 days.

- Water is crucial for sustaining the reactions that keep us alive. For instance, digestion, distribution of food through blood, removal of waste matter from the body.
- It cools automobile engines, nuclear power plants, steel mills and parts of heavy machinery in industrial units.
- It provides means of transportation on Earth's surface.
- Farmers need a large amount of water for the fields for growing fruits, vegetables and crops.
- We need water for drinking, cooking and cleaning.
- It is also used to generate electricity.

### **Self-Assessment Exercise 15.1**

**List household, industrial and agricultural uses of water.**

**Solution: Household water:**

We need water for drinking, cooking and cleaning.

**Industrial use of water:**

It cools automobile engines, nuclear power plants, steel mills and parts of heavy machinery in industrial units.

**Agriculture use of water:**

Farmers need a large amount of water for their fields for growing fruits, vegetables and crops.

**Q3. Describe the properties of water.**

**Ans: Properties of water:**

- i. Water is the only substance that exists in three different states on earth.
- ii. Pure water is transparent, colourless, odourless and tasteless. It boils at  $100^{\circ}\text{C}$  and freezes at  $0^{\circ}\text{C}$  at sea level.
- iii. Anomalous behaviour of water:

Density of most of the solids and liquids, generally increase on heating and decreases on cooling. Water, however, shows strange behaviour in this regard. On cooling it contracts upto  $4^{\circ}\text{C}$ . At this temperature its density becomes maximum. On further cooling water expands, hence its density decreases. So water expands when freezes. Because of this ice floats on water. The consequences of this strange behaviour are immense life on Earth. Ice forms on the surface of lakes only and insulates the lower layers of water. This enables fish and other aquatic organisms to survive in winter.

**iv. Heat capacity:**

Water has a high heat capacity. So much heat is required to raise the temperature of 1.0 g of water by  $1^{\circ}\text{C}$ . Conversely, much heat is given off by water for even a small drop in temperature. The vast amount of water on the surface of Earth thus acts as a giant heat reservoir to moderate daily temperature variations. For this reason water is an excellent cooler in industries.

**v. Vapourization:**

Water has a high heat of vapourization. So a large amount of heat is required to evaporate small amount of water. This is of enormous importance for us. How? Water (perspiration) from the skin. The property also accounts for the climate-modifying property of lakes and oceans. Thus in summer it is cooler near a large water body of water (lakes, rivers and seas) than in interior land areas.

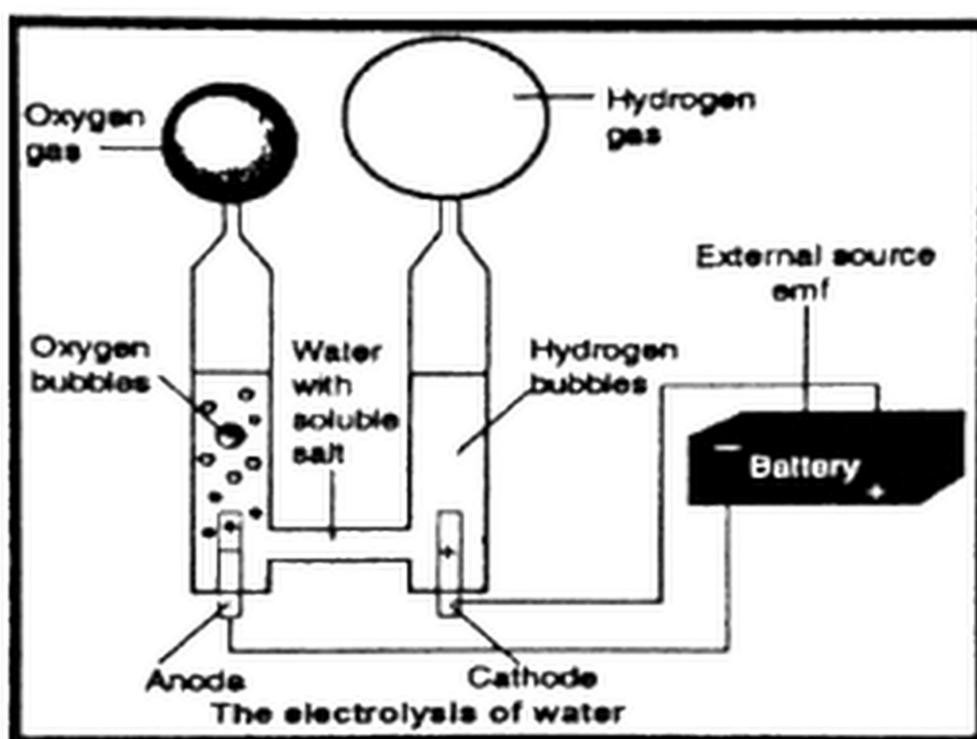
**Q4. Explain the composition of water?**

OR

**How can you split water?**

**Ans: Composition of water:**

Water is normally a poor conductor of electricity. However, when electricity is passed through acidified water in a voltameter, water decomposes. It gives hydrogen and oxygen. At which electrode hydrogen is produced?



The process is called electrolysis and the reaction can be written as



The splitting of water molecules produces double amount of hydrogen as compared to oxygen. This means hydrogen and oxygen in water are in the ratio of **2:1** by volume. Hydrogen is collected at cathode and oxygen is collected at anode.

**Q5. Water is a remarkably versatile solvent. Justify the statement.**

**Ans: Water as solvent:**

Water is very good at dissolving substances.

The ability of water to dissolve a wide variety of substances is due to its properties, the polarity of water molecules and the ability of water molecules to form hydrogen bonds.

Water molecules are strongly attracted to ions, polar molecules with which overcome the attractions between the molecules or ions of the other substance and in this way the substance dissolves. They may be ionic solids, polar substances and hydrogen bonded compounds. Therefore water is universal solvent.

**Q6. How does hard water differ from soft water?**

**Ans: Soft water:**

Water that easily gives lather with soaps and does not form scum is called soft water.

**Hard water:**

Water that gives little lather or forms scum with soap is called hard water.

**Q7. How does hardness produced in water?**

**Ans: Causes of hardness in water:**

Rainwater dissolves carbon dioxide as it falls through the atmosphere. Carbon dioxide reacts with water to produce carbonic acid, which is weak acid.



This carbonated water passes over or through the rocks containing calcium carbonate, the acid present in it attack these rocks. It slowly dissolves them, forming calcium and magnesium carbonates.



Some rocks may contain gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) or anhydride ( $\text{CaSO}_4$ ) or kieserite ( $\text{MgSO}_4 \cdot \text{H}_2\text{O}$ ) which is sparingly soluble in water. The presence of these dissolved salts causes the water to become hard.

### Self-Assessment Exercise 15.2

1. List substances that cause hardness in water.
2. Differentiate between soft and hard water.

**Solution:**

1. List substances that cause hardness in water?

Carbonate hardness compounds (Temporary Hardness)	Noncarbonated hardness compounds (Permanent Hardness)
Calcium carbonate ( $\text{CaCO}_3$ ) Magnesium carbonate ( $\text{MgCO}_3$ ) Calcium bicarbonate ( $\text{Ca}(\text{HCO}_3)_2$ ) Calcium hydroxide ( $\text{Ca}(\text{OH})_2$ )	Calcium Sulphate ( $\text{CaSO}_4$ ) Magnesium Sulphate ( $\text{MgSO}_4$ ) Calcium Chloride ( $\text{CaCl}_2$ ) Magnesium Chloride ( $\text{MgCl}_2$ )

Magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ )	
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Carbonate hardness is sometimes called **temporary hardness** because it can be removed by boiling water. Noncarbonated hardness cannot be broken down by boiling water. Noncarbonated hardness cannot be broken down by boiling water, so it is also known as **permanent hardness**.

## 2. Differentiate between soft and hard water?

The presence of calcium and magnesium salts in the form of hydrogen carbonate, chloride and Sulphate in water makes water 'hard'. Hard water does not give lather with soap.

Whereas, water free from soluble salts of calcium and magnesium is called soft water. It gives lather with soap.

Hard water forms scum (precipitate) with soap, therefore unsuitable for laundry but soft water does not form scum.

### Q8. Which water is soft, tap water or distilled water?

**Ans:** Tap water contains impurities ( $\text{CaSO}_4$ ,  $\text{MgSO}_4$ ) in the water that distilled water does not have. Therefore, distilled water is a soft water.

**Q9. Have you ever noticed that the pan which is regularly used for boiling water gets white or yellowish deposits at its bottom and sides?**

**Ans:** This is due to the boiler scales of  $\text{CaCO}_3$  and  $\text{MgCO}_3$ .

**Q10. Differentiate among temporary and permanent hard water?**

**OR**

**Describe the types of hardness of water?**

**Ans: Types of hardness of water:**

Hardness in water can be divided into two types, **temporary** and **permanent**.

**Temporary Hardness:**

Temporary Hardness is so called because it can be removed by boiling.

**Permanent hardness:**

Permanent hardness is so called because it cannot be removed by boiling.

Temporary hardness is caused by the presence of dissolved calcium or magnesium hydrogen carbonates. Whereas permanent hardness is caused by the presence of dissolved sulphates and chlorides of calcium or magnesium. Hard water hampers cleaning action of soap.

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**Scum:**

It is difficult to make the soap lather in hard water. Instead, the water becomes cloudy. This cloudiness is due to the formation of a white precipitate by the

reaction of  $\text{Ca}^{+2}$  or  $\text{Mg}^{+2}$  ions in hard water and soap. This white precipitate is known as scum.

### Science Titbits:

#### Detergents:

To overcome the problem of scum formation in hard water, detergents have been produced. Detergents do not produce a scum. This is because they do not react with calcium or magnesium ions present in hard water. Also, detergent molecules are biodegradable. Bacteria can easily break these molecules, so they do not persist in the environment.

**Q11. Describe the methods to remove temporary hardness?**

**Ans: Methods to remove temporary hardness:**

**i) By boiling:**

Hardness of water can be removed simply by boiling. During boiling the soluble calcium and magnesium hydrogen carbonates are decomposed forming insoluble carbonates. Since  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  ions are removed as insoluble carbonates, water becomes soft.



Where  $\text{M}=\text{Ca}^{+2}$  or  $\text{Mg}^{+2}$

Unfortunately, this method is too expensive to remove temporary hardness of water on the large scale.

**ii) By adding slaked lime (Clark's Method):**

Temporary hardness in water on the large scale can be removed by adding an estimated amount of slaked lime in it. The slaked lime reacts with the hydrogen carbonates to form insoluble carbonates.



(1)

### Self-Assessment Exercise 15.3

Write chemical equations to show the changes that occur when hard water containing calcium hydrogen carbonate and magnesium hydrogen carbonate is boiled.

**Solution:**



**Q12. Describe the methods to remove permanent hardness?**

**Ans: Methods to remove permanent hardness:**

**i) By adding washing soda:**

On the large-scale permanent hardness in water can be removed by adding washing soda ( $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ ).  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  ions are removed as their insoluble carbonates.



**ii) By ion exchange resins:**

The hard water is passed through a container filled with a suitable resin containing sodium ions. Zeolite is one of the natural ion exchangers. Chemically, it is sodium aluminum silicate. It is usually written as  $\text{Na}_2\text{Z}$ . The  $\text{Ca}^{+2}$  or  $\text{Mg}^{+2}$  ions causing the hardness are exchanged with  $\text{Na}^+$  ions in the resin.



Where  $\text{M}^{+2} = \text{Ca}^{+2}, \text{Mg}^{+2}$

The used-up zeolite can be regenerated by heating with concentrated solution of  $\text{NaCl}$ . This makes the process economical.



#### Self-Assessment Exercise 15.4

Complete the following reactions:

- i)  $\text{Ca}(\text{HCO}_3)_2_{(\text{aq})} \xrightarrow{\text{heat}}$
- ii)  $\text{Ca}(\text{HCO}_3)_2_{(\text{aq})} + \text{Ca}(\text{OH})_2 \longrightarrow$
- iii)  $\text{Ca}^{+2}_{(\text{aq})} + \text{Na}_2\text{Z} \longrightarrow$
- iv)  $\text{Mg}^{+2}_{(\text{aq})} + \text{Na}_2\text{Z} \longrightarrow$
- v)  $\text{Mg}^{+2}_{(\text{aq})} + \text{CO}_3^{-2}_{(\text{aq})} \longrightarrow$
- vi)  $\text{Ca}^{+2}_{(\text{aq})} + \text{CO}_3^{-2}_{(\text{aq})} \longrightarrow$

**Solution:**

- i)  $\text{Ca}(\text{HCO}_3)_2_{(\text{aq})} \xrightarrow{\text{heat}} 2\text{CaCO}_3_{(\text{s})} + \text{CO}_2_{(\text{g})} + 2\text{H}_2\text{O}_{(\text{l})}$
- ii)  $\text{Ca}(\text{HCO}_3)_2_{(\text{aq})} + \text{Ca}(\text{OH})_2 \longrightarrow 2\text{CaCO}_3_{(\text{s})} + 2\text{H}_2\text{O}_{(\text{l})}$
- iii)  $\text{Ca}^{+2}_{(\text{aq})} + \text{Na}_2\text{Z} \longrightarrow 2\text{Na}^+_{(\text{aq})} + \text{CaZ}_{(\text{s})}$
- iv)  $\text{Mg}^{+2}_{(\text{aq})} + \text{Na}_2\text{Z} \longrightarrow 2\text{Na}^+_{(\text{aq})} + \text{MgZ}_{(\text{s})}$
- v)  $\text{Mg}^{+2}_{(\text{aq})} + \text{CO}_3^{-2}_{(\text{aq})} \longrightarrow \text{MgCO}_3_{(\text{s})}$
- vi)  $\text{Ca}^{+2}_{(\text{aq})} + \text{CO}_3^{-2}_{(\text{aq})} \longrightarrow \text{CaCO}_3_{(\text{s})}$

**Q13. What do you understand by water pollution? Describe the causes of water pollution?**

**Ans: Water Pollution:**

The human activities such as household wastes, agricultural wastes, livestock wastes, pesticides, oil leaks, detergents, septic tanks, petroleum, natural gas production may result in contamination of water bodies.

**Household wastes:**

Household wastes include human wastes, livestock wastes, soaps and detergents, paints and oils, food and vegetables wastes, garbage wastes etc. Although detergents have strong cleansing action than soap, but they remain in water for long time and make water unfit for aquatic life.

Bacterial contents may cause infectious diseases such as cholera, jaundice, hepatitis, typhoid, dysentery etc.

**Industrial Wastes:**

These wastes may contain highly toxic compounds and heavy metals such as Pd, Cd, Cr, Hg, As, Sb etc. These toxic substances cause serious health problems, such as nervous disorder, anemia, high blood pressure, kidney diseases, nausea, dizziness and cancer.

Water from leather tanneries contain large quantities of chromium (VI) salts, chromium (VI) ions are highly toxic and known to cause cancer.

### **Self-Assessment Exercise 15.5**

**Compare modern water treatment and sewage treatment centres and processes.**

**Ans: Modern water treatment:**

The methods used include physical processes such as filtration, sedimentation and **distillation**; biological processes such as slow sand filters or biologically active carbon; chemical processes such as **flocculation** a chlorination and the use of electromagnetic radiation such as ultraviolet light.

### Sewage treatment centers:

Sewage water ➡ Sedimentation ➡ Chlorination ➡ Secondary Sewage Treatment

Flow sheet diagram for primary sewage treatment plan



Flow sheet diagram for secondary sewage treatment plant

### DO YOU KNOW?

**Q14. Describe the various types of waterborne diseases.**

**Ans: Waterborne disease:**

Unclean water supplies, poor sanitation and poor hygiene kill 2,668,000 people worldwide each year.

Water in swimming pools is purified from pathogenic organisms by aeration and chlorination.

Some water borne diseases are given below.

**i. Cholera:**

Cholera is an intestinal disease. It is caused by bacteria such as vibrio cholera, E. coli etc. which may be present in water contaminated with human wastes. It is characterized by vomiting and purging.

**ii. Dysentery:**

Dysentery is an intestinal disease. It is caused by parasite, Entamoeba. This infection is transmitted by fecal contamination of water or food by encysted organism. Patients have mild to severe abdominal cramps, diarrhea, chocolate colored stool with mucous and sometimes with blood.

**iii. Jaundice:**

This disease proceeds from obstruction of liver. Excess of bile from the liver enters in blood and causes yellowness of skin and eyes. It leads to loss of appetite, weakness and fatigue.

**iv. Hepatitis:**

Hepatitis is acute inflammation of liver. It is caused by viruses, and classified as Hepatitis A, B, C, D and E. Hepatitis A and E spreads through polluted water.

**v. Typhoid:**

Typhoid is a dangerous intestinal disease. It spreads by polluted water containing bacteria such as salmonella typhi, salmonella paratyphoid, and salmonella enteritidis. It is characterized by continuous fever between 101°F to 104°F and irregular pulse.

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Swimming is an important recreational activity. Biological contamination has lessened the recreational value of water. However, aeration and chlorination treatment of swimming pool water has lessened the threat of biological contamination.

### **Self-Assessment Exercise 15.6**

- 3. List some water borne diseases.**
- 4. List sources of water borne diseases.**

5. List steps used in sewage water treatment.
6. List steps used in raw water treatment.
7. Write effects produced by industrial wastes.
8. Write names of six household wastes.

**Solution:**

1. List some waterborne diseases.

- |               |               |
|---------------|---------------|
| i. Cholera    | ii. Dysentery |
| iii. Jaundice | iv. Hepatitis |
| v. Typhoid    |               |

2. List sources of water borne diseases.

- |                     |                       |
|---------------------|-----------------------|
| i. Household wastes | ii. Industrial wastes |
|---------------------|-----------------------|

3. List steps used in sewage water treatment.

- |                                 |                                |
|---------------------------------|--------------------------------|
| i. Primary sewage treatment     | ii. Secondary Sewage treatment |
| iii. Activated Sludge Treatment | iv. Chlorination               |

4. List steps used in raw water treatment.

- |                  |                  |
|------------------|------------------|
| i. Sedimentation | ii. Coagulation  |
| iii. Filtration  | iv. Chlorination |

5. Write effects produced by industrial wastes.

**Industrial wastes:**

Industrial wastes may contain highly compounds and heavy metals such as Pd, Cr, Cr, Hg, As, Sb etc. These toxic substances cause serious health problems, such as nervous disorder, anemia, high blood pressure, kidney diseases, nausea, dizziness and cancer.

Water from leather tanneries contains large quantities of chromium (VI) salts. Chromium (VI) ions are highly toxic and known to cause cancer. Industrial wastes cause irreversible degeneration of the environment causing serious health problems for public and marine life.

**6. Write names of six household wastes.**

**Household wastes:**

Household wastes include, human wastes, wastes, livestock wastes, soaps and detergents, paints and oil, food wastes, garbage etc.

**Q15. List two cations and three anions present in lake or surface water.**

**Ans:** Cations ( $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$ ,  $\text{Na}^{+1}$  and  $\text{K}^{+1}$ )

Anions ( $\text{SO}_4^{-2}$ ,  $\text{Cl}^{-1}$ , and  $\text{NO}_3^{-1}$ )

**Q16. Why the waste water chlorinated before it is returned to the water body?**

**Ans: Chlorination:**

The effluent from sewage plant is treated with chlorine to kill any remaining pathogenic microorganisms.

