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### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

#### Introduction to United Nations Sustainable Development Goals

The UN Sustainable Development Goals (UNSDGs), also known as the Global Goals, are a set of 17 interconnected goals adopted by UN member states in 2015. The goals are aimed at ending poverty, protecting the planet, and ensuring that all people enjoy peace and prosperity by the year 2030. Each goal has specific targets and indicators to track progress, and they are integrated and indivisible, meaning that they are interdependent and must be addressed together. The need for the UNSDGs is urgent, as they address some of the world's most pressing challenges, including poverty, inequality, climate change, and conflict. By working together to achieve these goals.



#### The 17 UN SDG goals are:

- 1) No poverty- End poverty in all its forms everywhere.
- 2) Zero hunger - End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
- 3) Good health and well-being- Ensure healthy lives and promote wellbeing for all at all ages.

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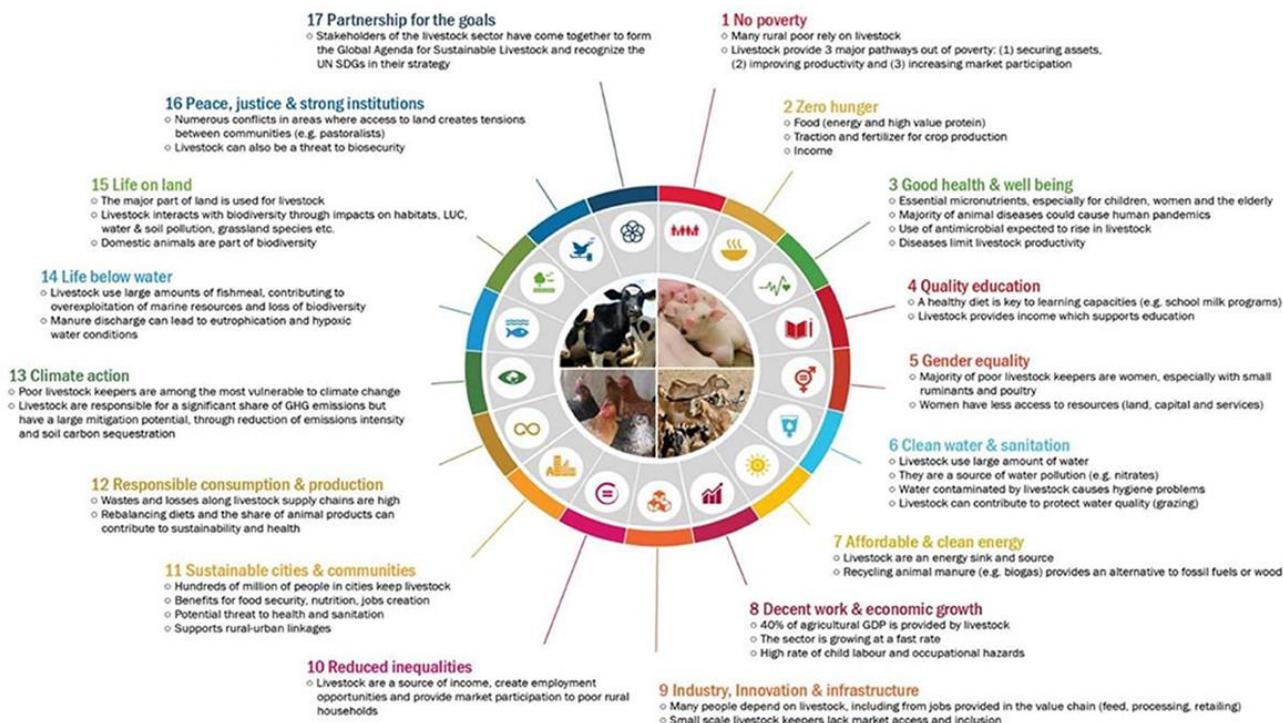
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- 4) Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- 5) Achieve gender equality and empower all women and girls.
- 6) Ensure availability and sustainable management of water and sanitation for all.
- 7) Ensure access to affordable, reliable, sustainable and modern energy for all.
- 8) Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all.
- 9) Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- 10) Reduce inequality within and among countries.
- 11) Make cities and human settlements inclusive, safe, resilient and sustainable.
- 12) Ensure sustainable consumption and production patterns.
- 13) Take urgent action to combat climate change and its impacts.
- 14) Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- 15) Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and biodiversity loss.
- 16) Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
- 17) Strengthen the means of implementation and revitalize the global partnership for sustainable development. Within the goals are 169 targets for example under goal one, the targets include reducing by at least half the number of people living in poverty by 2030.

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### Objectives of the United Nations Sustainable Development Goals:

- The main objectives of the United Nations are the maintenance of international peace and security, the promotion of the well-being of the peoples of the world, and international cooperation to these ends.
- The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.
- The Sustainable Development Goals (SDGs) aim to transform our world. They are a call to action to end poverty and inequality, protect the planet, and ensure that all people enjoy health, justice and prosperity.
- The SDGs are a bold commitment to finish what we started, and end poverty in all forms and dimensions by 2030. This involves targeting the most vulnerable, increasing basic resources and services, and supporting communities affected by conflict and climate-related disasters.
- Three core elements of sustainable development are economic growth, social inclusion and environmental protection, allowing prosperity for now and future generations.

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#### **Need of the UNSDGs:**

- Global Challenges: Environmental degradation- Climate change, biodiversity loss, pollution, and resource depletion threaten the planet and our well-being.
- Social inequality: Poverty, hunger, lack of access to healthcare and education are widespread, undermining human rights and dignity.
- Economic instability: Inequalities between and within countries, unemployment, and unsustainable consumption patterns hinder economic development.
- Need for a collective approach: These challenges are complex and interconnected, requiring collaboration at local, national, and international levels. The SDGs provide a shared framework for action, ensuring all countries participate and contribute.
- Addressing multiple needs simultaneously: The SDGs recognize that tackling one challenge alone is not enough. They address interconnected issues like poverty, hunger, health, education, and climate change holistically and simultaneously.
- Creating a future for all: The SDGs emphasize leaving no one behind, aiming to provide equal opportunities and improve the lives of the most vulnerable populations.
- Empowering action: The SDGs provide a clear roadmap for governments, businesses, civil society, and individuals to take concrete action and contribute to a better future.
- Measuring progress: Each SDG has specific targets and indicators to track progress and hold stakeholders accountable.
- Inspiring change: The SDGs serve as a powerful vision and call to action, inspiring individuals and communities to work towards a more sustainable future.
- The UN SDGs are critical because they offer a shared vision, framework, and roadmap for addressing the world's most pressing challenges and creating a more just and sustainable future for all.

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# Solid waste management for sustainable environment



### Causes, effects and its control measures:

Solid waste management (SWM) is the collection, transportation, processing, or disposal of solid waste. Solid waste can be generated from industrial, residential, and commercial activities. SWM is important for public health and environmental protection. **Sustainable Development Goal (SDG) 12: "Responsible Consumption and Production"** directly relates to solid waste management.

**Key aspects:** Reducing waste generation, efficient collection and processing, and minimizing environmental impact.

**Causes of solid waste:** The main causes of solid waste are,

- **Population growth:** As the population grows, so does the amount of waste generated.
- **Economic development:** As economies develop, people consume more goods and produce more waste. Industrial activity generates diverse waste streams with potential hazards.
- **Technological change:** New technologies create new products, which can lead to more waste.
- **Lack of awareness and infrastructure:** Improper waste disposal practices exacerbate the problem.

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#### **Effects of solid waste:**

Solid waste can have a number of negative effects on the environment and human health. These effects include:

- Environmental/Climate change: Solid waste contributes to climate change by releasing greenhouse gases. Landfills pollute air, water, and soil. Organic waste decomposes anaerobically, releasing methane, a potent greenhouse gas.
- Public health: Disease vectors breed in unmanaged waste, and air pollution harms respiratory health. Solid waste can cause health problems such as respiratory infections, skin diseases, and diarrhea.
- Economic: Inefficient waste management strains resources and generates cleanup costs.

#### **Control measures for solid waste:**

There are a number of control measures that can be used to reduce the amount of solid waste generated and its negative effects on the environment and human health. These measures include:

- Waste prevention: This involves reducing the amount of waste generated in the first place.
- Waste reduction: This involves reducing the amount of waste that is sent to landfills or incinerators. Promote reuse, repair, and composting. Minimize packaging and unnecessary consumption.
- Waste recycling: This involves converting waste into new products. Collect and process materials like paper, plastic, metal, and glass for reuse. Biodegradable organic waste can be transformed into valuable soil amendment.
- Waste disposal: This involves disposing of waste in a safe and environmentally friendly manner. Dispose of residual waste in sanitary landfills with proper liner systems and leachate management.
- Industrial Waste treatment: Treat specific waste streams depending on their composition and potential hazards.

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## Circular Economy



A circular economy is an economic system that aims to minimize waste and resource depletion by keeping materials in use for as long as possible. In a circular economy, resources are kept in use for as long as possible, and waste is minimized. Design for disassembly, extended producer responsibility, product life extension, and resource recovery.

The circular economy can be applied to solid waste management by,

- Designing products that are easy to recycle or reuse.
- Creating markets for recycled materials.
- Investing in waste prevention and reduction programs.
- By adopting a circular economy approach, we can reduce the amount of solid waste generated and its negative effects on the environment and human health.

Public education and awareness play a crucial role in promoting responsible waste management practices. Technological advancements like waste-to-energy conversion offer additional solutions. International collaboration and policy frameworks are essential for addressing global waste challenges.

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## **Water Chemistry for Sustainable Environment**

**Water** is a colourless and odorless substance found all over the Earth. **Water** is made up of billions of molecules. **Water** on our planet flows as **liquid** in rivers, streams and oceans; is **solid** as ice at the North and South Poles; and is **gas** (vapour) in the atmosphere.

### **Sources of water:**

- **Surface water:**

It is available on the surface of the earth either in still form or in flowing form.

Example: rain water, river water, lake water and sea water.

- **Under ground water:**

It is developed by any type of well or spring from beneath the surface of the ground whether the water flows from the well or spring by natural force or is withdrawn by pumping, other mechanical device or artificial process.

Example: Springs, well and tube wells.

### **Impurities in water:**

The major categories of impurities found in the water may be broadly classified into four categories. Dissolved impurities, Suspended impurities, Dissolved gases and Organic matter.

- **Dissolved impurities:**

Dissolved impurities mainly consist of soluble salts of Ca, Mg, Na. i.e. bicarbonates, chlorides, sulphates of Ca, Mg and Na. In addition, small amount of nitrates, nitrites, silicates, ammonium and ferrous salts are also present. These salts are derived from the rock and soil with which the water is in contact. Thus, the water which is in contact with limestone contains  $\text{CaCO}_3$ , Since the  $\text{CO}_2$  dissolved in water interacts with limestone.



Similarly water which is in contact with magnesite contains  $\text{MgCO}_3$ .



In general ground water contains more dissolved salts than the surface water.

- **Suspended impurities:**

Suspended matter may be inorganic or organic in nature. The inorganic materials include small particles of sand, clay, silica, hydroxides of iron and aluminium, derived from the erosion of soil. Some of these have large particle size and therefore settle down readily. Others are fine particles and colloidal in nature. These do not settle easily. The organic suspended impurities are decaying vegetable matter and are due to microorganisms. These are also present in the colloidal form. This causes turbidity of water.

## Department of Chemistry

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- **Dissolved gases:**

Water contains mainly CO<sub>2</sub> and O<sub>2</sub> along with SO<sub>2</sub>, NH<sub>3</sub> and oxides of nitrogen all of which are derived from atmosphere.

- **Organic matter:**

Organic impurities in water arise from the decay of vegetable matter. Mainly organic acids and from farming, paper making and domestic and industrial waste. These include detergents, fats, oils, solvents and residues from pesticides and herbicides. Water also contaminated with sewage and human excreta

 **Potable water:**

Water that is safe enough to be consumed by human beings is called as potable water. The word potable is a Latin word meaning drinkable. WHO's guidelines for drinking-water quality were set up in Geneva in the year 1993.

 **Water quality specification by WHO :**

Sl. No.	Parameter	Quantity
1	Copper	2 mg
2	Aluminium	0.2 mg/L
3	Lead	< 0.01 mg/L
4	Mercury	< 0.001 mg/L
5	Cadmium	< .003 mg/L
6	Antimony	< 0.005 mg/L
7	Arsenic	< 0.01mg/L
8	Chloride	< 250 mg/L
9	Fluoride	< 1.5mg/L
10	Hardness	< 200mg/L
11	Chlorine	< 5 mg/L
12	Conductivity	250 $\mu$ S/cm
13	Microorganisms	0 in 100 to 250 cm <sup>3</sup>

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### **ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY**

#### DETERMINATION OF TOTAL HARDNESS OF WATER USING

##### EDTA BY COMPLEXOMETRIC TITRATION

**Aim:** To estimate the Total Hardness present in the supplied sample of water using EDTA by complexometric titration.

**Apparatus:** Burette, pipette, conical flask, volumetric flask, beakers, funnel and glass-rod.

**Chemicals:** Disodium salt of ethylene diamine tetra acetic acid crystals, Eriochrome black-T indicator and Buffer solution (Mixture of NH<sub>4</sub>Cl and NH<sub>4</sub>OH).

#### **Theory:**

**Hardness** is that characteristic property of water, which prevents lather formation with soap solution. There are two types of hardness, viz., temporary and permanent hardness.

**Temporary hardness** of water is due to the presence of soluble salts of bicarbonates of calcium and magnesium in water that can be removed merely by boiling. Boiling of water converts the bicarbonates of soluble salts present in the water into insoluble carbonates and hydroxides of metal ions, which can be removed by filtration.



**Permanent hardness** of water is due to the presence of soluble salts of chlorides, sulphates and nitrates of Ca and Mg which cannot be removed by boiling the water. Hence permanent hardness is due to the presence of these salts.

**Total hardness** of water is the algebraic sum of temporary and permanent hardness and it is expressed in terms of CaCO<sub>3</sub> equivalent hardness in ppm. or mg./lit., because

- The amount of Ca is maximum in the earth's crust compared to any other hardness producing substances.
- Its molecular weight is 100, which makes mathematical calculations easier.
- It is most insoluble salt, thus can be easily precipitated.

Total hardness of water permissible in potable water is 200 ppm. Water samples having Total hardness greater than 250 ppm causes scale deposits in plumbing, boilers and leads to corrosion.

The hardness of water is determined by using Std. disodium salt of EDTA solution and EBT indicator.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Procedure:

- **Preparation of Standard Na<sub>2</sub>EDTA solution:**

Dissolve the supplied disodium salt of EDTA ('W'g.) in a 250ml clean beaker by adding four test tubes of warm distilled water. Transfer this solution to 250ml volumetric flask. Wash the beaker 2-3 times with distilled water thoroughly and transfer the same in to the volumetric flask. Dilute up to the mark of the volumetric flask using distilled water. Shake the flask well to make the solution homogeneous. Rinse and fill the burette with the prepared std. disodium salt of EDTA solution.

$$\text{Weight of disodium salt of EDTA} = 'W' \text{ g.}$$

$$\text{Molecular weight of disodium salt of EDTA} = 372.24$$

$$\text{Molarity of disodium salt of EDTA} = \frac{W \times 4}{372.24} = 'x' \text{ M.}$$

- **Titration:**

Pipette out **50 ml of the supplied hard water sample** into a clean conical flask. Add about **5ml of buffer solution, 2-3 drops of EBT indicator** and titrate against std. disodium salt of EDTA solution until a sharp colour changes from **wine red to purple to clear blue**. Note down the burette reading and perform another 2 sets of titrations for accuracy.

B.R. →	I ml.	II ml.	III ml.	Mean BR
B.L. ↓				... 'V' ml
Final level				
Initial level				
Difference				

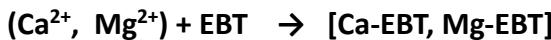
Calculate the amount of total hardness present in the supplied sample of hard water in terms of calcium carbonate equivalent hardness, in ppm, using the standard conversion factor.

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### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Reactions:



Blue      Less stable, wine-red



Colourless      Stable, colourless



Blue      Less stable, wine-red      Stable, colourless      Blue

#### Calculation:

The given **Conversion Factor** is:

$$1000 \text{ ml of } 1\text{M Na}_2\text{EDTA solution} \equiv 100 \text{ g. of CaCO}_3 \text{ equivalent hardness.}$$

i.e. 1ml of 1M Na<sub>2</sub>EDTA solution  $\equiv$  0.1 g. of CaCO<sub>3</sub> equivalent hardness.

Now, 'V' ml of 'x' M Na<sub>2</sub>EDTA solution  $\equiv$  0.1  $\times$  'x'  $\times$  'V' = 'y' g. of CaCO<sub>3</sub>.

i.e., **50 ml** of hard water sample contains = 'y' g. of CaCO<sub>3</sub> equivalent hardness.

Therefore, **1000ml** of hard water sample  $\equiv$   $\frac{'y' \times 1000}{50}$  = 'z' g./lit. of CaCO<sub>3</sub>

Hence, Total Hardness of water in terms of CaCO<sub>3</sub>, in ppm. = 'z'  $\times$  1000 mg/lit. = 'H' ppm.

i.e., **Total Hardness** = 'H' ppm.

**Result:** Total Hardness of Water in terms of CaCO<sub>3</sub> equivalent hardness = 'H' ppm.

#### NOTE:

- Molecular weight of CaCO<sub>3</sub> = 100 g/mol
- Equivalent weight of CaCO<sub>3</sub> = 50
- Molecular weight of Ca(HCO<sub>3</sub>)<sub>2</sub> = 162 g/mol
- Molecular weight of Mg(HCO<sub>3</sub>)<sub>2</sub> = 146 g/mol
- Molecular weight of CaCl<sub>2</sub> = 111 g/mol
- Molecular weight of MgCl<sub>2</sub> = 95 g/mol
- Molecular weight of CaSO<sub>4</sub> = 136 g/mol
- Molecular weight of MgSO<sub>4</sub> = 120 g/mol
- Molecular weight of Ca(NO<sub>3</sub>)<sub>2</sub> = 164 g/mol
- Molecular weight of Mg(NO<sub>3</sub>)<sub>2</sub> = 148 g/mol

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### NUMERICAL PROBLEMS ON TOTAL HARDNESS

1. Calculate the temporary and permanent hardness of water sample which contains 16.2 mg/lit of  $\text{Ca}(\text{HCO}_3)_2$ , 29.2 mg/lit of  $\text{Mg}(\text{HCO}_3)_2$ , 33.3 mg/lit of  $\text{CaCl}_2$ , 18.0 mg/lit of  $\text{MgSO}_4$ , and 55.0 mg/lit of  $\text{NaCl}$ .

Given:

- Mass of  $\text{Ca}(\text{HCO}_3)_2$  = 16.2 mg/lit
- Mass of  $\text{Mg}(\text{HCO}_3)_2$  = 29.2 mg/lit
- Mass of  $\text{CaCl}_2$  = 33.3 mg/lit
- Mass of  $\text{MgSO}_4$  = 18.0 mg/lit
- Mass of  $\text{NaCl}$  = 55.0 mg/lit

Solution:

- ❖  $\text{CaCO}_3$  equivalent = 
$$\frac{\text{Mass of hardness producing salt} \times \text{Molecular weight of } \text{CaCO}_3}{\text{Molecular weight of harness producing salt}}$$
- $\text{CaCO}_3$  equivalent of 16.2 mg/lit of  $\text{Ca}(\text{HCO}_3)_2$  =  $(16.2 \times 100) / 162 = 10 \text{ ppm}$ .
  - $\text{CaCO}_3$  equivalent of 29.2 mg/lit of  $\text{Mg}(\text{HCO}_3)_2$  =  $(29.2 \times 100) / 146 = 20 \text{ ppm}$ .
  - $\text{CaCO}_3$  equivalent of 33.3 mg/lit of  $\text{CaCl}_2$  =  $(33.3 \times 100) / 111 = 30 \text{ ppm}$ .
  - $\text{CaCO}_3$  equivalent of 18.0 mg/lit of  $\text{MgSO}_4$  =  $(18.0 \times 100) / 120 = 15 \text{ ppm}$ .
  - $\text{NaCl}$  does not impart hardness.
- ❖ Temporary hardness is due to the presence of  $\text{Ca}(\text{HCO}_3)_2$  and  $\text{Mg}(\text{HCO}_3)_2$ .
- ❖ Permanent hardness is due to the presence of  $\text{CaCl}_2$  and  $\text{MgSO}_4$ .
- ❖ Total Hardness = Temporary Hardness + Permanent Hardness
- Temporary Hardness =  $10 + 20 = 30 \text{ ppm}$
  - Permanent Hardness =  $30 + 15 = 45 \text{ ppm}$
  - Total Hardness =  $30 + 45 = 75 \text{ ppm}$ .

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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- 2. 50 ml of water sample requires 10ml of 0.01 N EDTA when titrated using buffer solution whose pH is 10 to attain the end point. Calculate the total hardness of water sample in terms of ppm equivalent of  $\text{CaCO}_3$  per lit.**

**Given:**

- Volume of water sample =  $V_1 = 50\text{ml}$
- Normality of water sample in terms of hardness =  $N_1$
- Volume of EDTA =  $V_2 = 10\text{ml}$
- Normality of EDTA =  $N_2 = 0.01\text{N}$

**Solution:**

- ❖  $V_1 \times N_1 = V_2 \times N_2$
- Therefore,  $N_1 = V_2 \times N_2 / V_1 = (10 \times 0.01) / 50 = 0.002\text{N}$ .
- ❖ **Total Hardness water sample = (Normality of water sample in terms of hardness X Equivalent weight of  $\text{CaCO}_3$  X 1000 ppm.)**
- Total Hardness =  $0.002 \times 50 \times 1000 \text{ ppm}$
- ❖ **Total Hardness = 100 ppm.**

- 3. 30 ml of hard water sample requires 25 ml of 0.006 M EDTA when titrated using buffer solution whose pH is 10 to attain the end point. Calculate the total hardness of water sample in terms of ppm equivalent of  $\text{CaCO}_3$  per lit.**

**Given:**

- Volume of hard water sample =  $V_1 = 30 \text{ ml}$
- Molarity of water sample in terms of hardness =  $M_1$
- Volume of EDTA =  $V_2 = 25 \text{ ml}$
- Molarity of EDTA =  $M_2 = 0.006 \text{ M}$

**Solution:**

- ❖  $V_1 \times M_1 = V_2 \times M_2$
- Therefore,  $M_1 = V_2 \times M_2 / V_1 = (25 \times 0.006) / 30 = 0.005 \text{ M}$ .
- ❖ **Total Hardness water sample = (Molarity of water sample in terms of hardness X Molecular weight of  $\text{CaCO}_3$  X 1000 ppm.)**
- ❖ **Total Hardness =  $0.005 \times 100 \times 1000 \text{ ppm}$  ;**
- ❖ **Total Hardness = 500 ppm.**

## Department of Chemistry

### **ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY**

#### **Determination of Dissolved Oxygen in water by Winkler's method**

**Aim:** To estimate the amount of Dissolved Oxygen in the supplied sewage sample by Winkler's method.

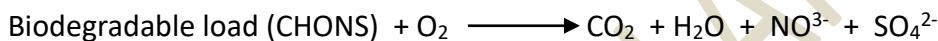
**Apparatus:** 300 ml BOD bottle, Burette, 10 ml pipettes, 100 ml measuring cylinder, 250 ml volumetric flask, beakers, conical flasks and funnel.

**Chemicals:** Manganese sulphate, alkaline potassium iodide, sodium thiosulphate, sulphuric acid and starch indicator.

#### **Theory:**

Dissolved oxygen is used as an indicator for the health of a water body. Aquatic animals need dissolved oxygen (DO) to live.

**Winkler's Method** is a technique used to measure **Dissolved Oxygen (DO)** in freshwater systems by **Iodometric titration**.



#### **Principle:**

The **DO in water oxidizes KI solution to liberate equivalent quantity of iodine**, which is then **titrated against std. Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution using starch as an indicator**.

#### **Theory:**

Winkler's Method is a technique used to measure dissolved oxygen in freshwater systems. Dissolved oxygen is used as an indicator for the health of a water body, where higher dissolved oxygen concentrations are correlated with high productivity and little pollution. This test is performed on-site, as delays between sample collections and testing may result in an alteration in oxygen content. Determination of Dissolved Oxygen is important for boiler feed water as well as in sanitary engineering practice. DO test is used to control the amount of oxygen in boiler feed water by mechanical, physical and chemical methods. DO causes corrosion in boilers. It is needed for living organisms to maintain their biological processes. DO is also important in precipitation and dissolution of inorganic substances in water.

Aquatic animals need dissolved oxygen (DO) to live. Fish, invertebrates, plants and aerobic bacteria all require oxygen for respiration. The amount of oxygen that can be dissolved in the water is reduced with increased temperature. The temperature effect is compounded by the fact that living organisms increase their activity in warm water, requiring more oxygen to support their metabolism. Fish and invertebrates that can move will leave areas with low DO.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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- DO levels < 3 ppm are stressful to most aquatic organisms.
- DO levels < 2 ppm will not support fish.
- DO = 5-6 ppm is required for growth and activity of most aquatic organisms.
- DO = 8 ppm cause corrosion in boiler.

DO test helps to assess the raw water quality and to keep a check on stream pollution. It is the basis of BOD test, which is an important parameter in evaluating the pollution potential of domestic and industrial wastes.

The principle involved in this method is the DO in water oxidizes KI solution to liberate equivalent quantity of iodine, which is then titrated against std.  $\text{Na}_2\text{S}_2\text{O}_3$  solution using starch indicator. However, since DO in water is in molecular state and is not capable of reacting with KI, therefore an oxygen carrier such as manganese hydroxide is used.

The method involves introducing a concentrated solution of  $\text{MnSO}_4$ , alkaline KI into the water sample. The white precipitate of  $\text{Mn}(\text{OH})_2$  which is formed is oxidized by oxygen in water sample to give a brown precipitate of basic manganic oxide,  $\text{MnO}(\text{OH})_2$ . This  $\text{MnO}(\text{OH})_2$  in acidic medium dissolves and liberates nascent oxygen. This nascent oxygen in acidic medium liberates free iodine from the added KI in an equivalent amount of Dissolved Oxygen in water sample. This liberated iodine is then titrated against standard sodium thiosulphate solution using starch as the indicator.

**Temperature-Oxygen Solubility Relationship**

Temperature ( $^{\circ}\text{C}$ )	Oxygen Solubility (mg/L)
0	14.6
5	12.8
10	11.3
15	10.2
20	9.2
25	8.6
100	0

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### **Procedure:**

##### **(A) Titration:**

Collect 250ml of the water sample in a 300ml BOD bottle, avoiding contact with air. To the Bottle sample, add with the help of pipette, 5ml of  $\text{MnSO}_4$  and 5ml of alkaline KI reagents. Stopper the bottle immediately and shake well by inverting the bottle 3 to 4 times and allow it stand for 5 minutes. The brown precipitate of basic manganic oxide,  $\text{MnO(OH)}_2$  gets settles down. Now, add one test tube of dil.  $\text{H}_2\text{SO}_4$ , insert the stopper and shake well till the precipitate is completely dissolved. The **reaction mixture** acquires **brownish yellow colour** due to the **liberation of iodine**.

Take **100 ml of the above reaction mixture** into a conical flask and **titrate against  $\text{Na}_2\text{S}_2\text{O}_3$**  solution until the reaction mixture becomes **pale yellow colour**, then add 1ml of freshly prepared **starch** solution. The reaction mixture turns into **deep blue colour** due to the formation of less stable **starch-iodide complex**. Continue the titration till the **blue colour disappears**. Note down the burette reading and perform another 2 sets of titrations for accuracy.

The amount of Dissolved Oxygen present in the water sample is calculated by using standard conversion factor:

$$\text{C.F: } 1000\text{ml of 1N } \text{Na}_2\text{S}_2\text{O}_3 \text{ solution} \equiv 8\text{g. of Dissolved Oxygen.}$$

#### **Reactions:**

- $\text{MnSO}_4 + 2\text{NaOH} \rightarrow \text{Mn(OH)}_2 + \text{Na}_2\text{SO}_4$
- $2 \text{Mn(OH)}_2 + \text{O}_2 \rightarrow 2\text{MnO(OH)}_2$   
Basic Manganic oxide
- $\text{MnO(OH)}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{MnSO}_4 + 2\text{H}_2\text{O} + [\text{O}]$
- $2\text{KI} + \text{H}_2\text{SO}_4 + [\text{O}] \rightarrow \text{K}_2\text{SO}_4 + \text{H}_2\text{O} + \text{I}_2$
- $\text{I}_2 + \text{Starch} \rightarrow [\text{Starch-Iodide}]$  Unstable blue coloured complex
- $\text{I}_2 + 2\text{Na}_2\text{S}_2\text{O}_3 \rightarrow \text{Na}_2\text{S}_4\text{O}_6 + 2\text{NaI}$   
Sodium tetrathionate

#### **Record of Observations:**

- Solution in burette: 'x' N  $\text{Na}_2\text{S}_2\text{O}_3$  solution.
- Solution in BOD bottle: 250ml water sample + 5ml  $\text{MnSO}_4$  + 5ml alkaline KI + dil.  $\text{H}_2\text{SO}_4$ .
- Solution in conical flask: 100ml reaction mixture.
- Indicator used: 1 ml starch solution.
- Colour change: **Brownish yellow**  $\rightarrow$  **Pale yellow**  $\rightarrow$  **Deep blue**  $\rightarrow$  Disappearance of blue colour.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Tabulation:

B.R. →	I ml.	II ml.	III ml.	Mean BR
B.L. ↓				... 'V' ml
Final level				
Initial level				
Difference				

#### Calculation:

Conversion Factor: 1000 ml of 1N  $\text{Na}_2\text{S}_2\text{O}_3$  solution  $\equiv$  8g. of Dissolved Oxygen.

i.e. 1 ml of 1N  $\text{Na}_2\text{S}_2\text{O}_3$  solution  $\equiv$  0.008g. of Dissolved Oxygen.

Now, 'V' ml of 'x' N  $\text{Na}_2\text{S}_2\text{O}_3$  solution  $\equiv$   $0.008 \times x \times V = y$  g. of Dissolved Oxygen.

i.e., 100 ml of water sample contains = 'y' g. of Dissolved Oxygen.

Therefore, 1000 ml of water sample contains  $\frac{y \times 1000}{100} = z$  g./lit. of Dissolved Oxygen.

Hence, amount of Dissolved Oxygen present in the water sample, in ppm = 'z'  $\times$  1000 mg /lit.

❖ Dissolved Oxygen present in the water sample = 'D' ppm.

#### BIOLOGICAL OXYGEN DEMAND

**BOD** is defined as the number of milligrams of Dissolved Oxygen required for the oxidation of biologically oxidizable impurities present in 1000 ml of waste water under aerobic conditions at 20 °C over a period of 5 days.

❖ Biological Oxygen Demand (BOD):

$$\text{BOD} = \frac{(D_1 - D_2) \times B}{A} \text{ ppm.}$$

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### NUMERICAL PROBLEMS ON DISSOLVED OXYGEN

1. In the iodometric titration of Winkler's method, 100 ml of waste water requires 15 ml of 0.05 N sodium thiosulphate solution to attain the endpoint. Calculate the dissolved oxygen present in the given sample of waste water.

Volume of reaction mixture used for titration = ' $V_s$ ' = 100ml

Volume of  $\text{Na}_2\text{S}_2\text{O}_3$  consumed for titration =  $V_1$  = 15 ml

Normality of  $\text{Na}_2\text{S}_2\text{O}_3$  solution =  $N_1$  = 0.05N

Normality of reaction mixture =  $N_s$

❖ Dissolved Oxygen, DO:

$$V_s \times N_s = V_1 \times N_1$$

$$N_s = V_1 N_1 / V_s = (15 \times 0.05) / 100 = 0.0075 \text{ N}$$

Dissolved Oxygen in Bottle, DO = Normality of reaction mixture x Equivalent weight of Oxygen x 1000 ppm

$$\text{Dissolved Oxygen, DO} = N_s \times 8 \times 1000 = 0.0075 \times 8 \times 1000 = 60 \text{ ppm}$$

2. In the iodometric titration of Winkler's method, 100 ml of waste water requires 20 ml of 0.02 N  $\text{Na}_2\text{S}_2\text{O}_3$  solution to attain the endpoint. Calculate DO present in a given water sample.

Volume of reaction mixture used for titration = ' $V_s$ ' = 100ml

Volume of  $\text{Na}_2\text{S}_2\text{O}_3$  consumed for titration =  $V_1$  = 20 ml

Normality of  $\text{Na}_2\text{S}_2\text{O}_3$  solution =  $N_1$  = 0.02N

Normality of reaction mixture =  $N_s$

❖ Dissolved Oxygen, DO:

$$V_s \times N_s = V_1 \times N_1$$

$$N_{DO} = V_1 N_1 / V_s = (20 \times 0.02) / 100 = 0.004 \text{ N}$$

Dissolved Oxygen in Bottle, DO = Normality of reaction mixture x Equivalent weight of Oxygen x 1000 ppm

$$\text{Dissolved Oxygen, DO} = N_s \times 8 \times 1000 = 0.004 \times 8 \times 1000 = 32 \text{ ppm}$$

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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3. 100 ml of waste water containing 630 ppm dissolved O<sub>2</sub> was diluted with 200 ml of distilled water and kept in a bottle at 20 °C for 5 days. Dissolved O<sub>2</sub> contents of the resulting water was then found to be 480 ppm. Calculate the BOD of the sample.

❖ Biological Oxygen Demand (BOD):

$$\text{BOD} = \frac{(D_1 - D_2) \times B}{A} \text{ ppm.}$$

$$\text{BOD} = \frac{(630 - 480) \times 300}{100} \text{ ppm}$$

- BOD = 450 ppm.

## CHEMICAL OXYGEN DEMAND

COD is defined as the number of milligrams of Oxygen required for the oxidation of both biologically and chemically oxidizable impurities present in 1000 ml of waste water using strong oxidizing agent like K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>.

### Determination of COD by Redox reaction

**Aim:** To estimate the amount of **Chemical Oxygen Demand** present in the supplied sewage sample by redox reaction.

**Apparatus:** Round bottom flask, water condenser, Burette, pipette, conical flasks and funnel.

**Chemicals:** Potassium dichromate, 1:1 sulphuric acid, mercuric sulphate, silver sulphate and ferrous ammonium sulphate (FAS) and ferroin indicator.

**Theory:**

Chemical Oxygen Demand represents the total amount of oxygen required to oxidize all oxidizable impurities present in a sample of sewage wastes. COD is always greater than BOD since in COD measurement, both biodegradable and non-biodegradable load are completely oxidized. The difference in COD and BOD is equivalent to the quantity of biologically resistant organic matter.

COD is a satisfactory quantitative method for measuring total organic load. It is preferable to BOD as the results are reliable. COD is a rapidly measurable parameter and needs 2 hours for completion.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Procedure:

- **Sample Titration:**

A definite known volume (' $V_s$ ' ml) of **sewage sample** was pipetted out into a round bottom flask. A **definite known excess of  $K_2Cr_2O_7$**  was pipetted out into the same round bottom flask. To the reaction mixture, one test tube of **1:1  $H_2SO_4$**  containing  **$HgSO_4$**  and  **$Ag_2SO_4$**  was added ( $HgSO_4$  prevents  $Cl^-$  ion interference and  $Ag_2SO_4$  catalyzes the oxidation of organic compounds). The round bottom flask was fitted with a **water condenser** and the reaction mixture was **refluxed for 2 hours**.

The above reaction mixture was cooled and transferred into a conical flask. Now, **4-5 drops of ferroin indicator** was added and the **reaction mixture turns into blue-green colour**. The **reaction mixture was titrated against ferrous ammonium sulphate** taken in the burette until a **sharp colour changes from blue-green to red-brown**. Note down the burette reading (' $A$ ' ml).

Burette Level	Burette Reading
Final level	
Initial level	
Difference	...' $A$ ' ml

- **Blank Titration:**

Same volume of  $K_2Cr_2O_7$  was pipetted out into a conical flask. To this, one test tube of **1:1  $H_2SO_4$**  containing  $HgSO_4$  and  $Ag_2SO_4$  and **4-5 drops of ferroin indicator** were added and the **reaction mixture turns into blue-green colour**. This **reaction mixture was titrated against ferrous ammonium sulphate** taken in the burette until a **sharp colour changes from blue-green to red-brown**. Note down the burette reading (' $B$ ' ml).

Burette Level	Burette Reading
Final level	
Initial level	
Difference	...' $B$ ' ml

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Calculation:

Volume of sewage sample taken = ' $V_s$ ' ml

Normality of reaction mixture (sewage sample) in terms of COD =  $N_{COD}$

Volume of FAS consumed in sample titration =  $A$  ml.

Volume of FAS consumed in blank titration =  $B$  ml.

Volume of  $K_2Cr_2O_7$  consumed in satisfying COD in terms of FAS solution =  $(B-A)$  ml

Normality of FAS solution =  $N_{FAS}$

#### ❖ Chemical Oxygen Demand (COD):

$$V_s N_{COD} = (B-A) N_{FAS}$$

$$N_{COD} = (B-A) N_{FAS} / V_s$$

Chemical Oxygen Demand of sewage sample, **COD** = Normality of reaction mixture (sewage sample) in terms of COD  $\times$  Equivalent weight of Oxygen  $\times$  1000 ppm

$$COD = N_{COD} \times 8 \times 1000 \text{ ppm.}$$

#### NUMERICAL PROBLEMS ON COD

1. 20ml of sewage sample for COD is reacted with 25ml of  $K_2Cr_2O_7$  and the un-reacted  $K_2Cr_2O_7$  requires 9.0ml of N/4 FAS solution. Under similar conditions, in blank titration, 15.0ml of FAS is used up. Calculate the COD of the sewage sample.

#### Given:

- Volume of sewage sample taken = ' $V_s$ ' = 20ml
- Normality of reaction mixture (sewage sample) in terms of COD =  $N_{COD}$
- Volume of FAS consumed in sample titration =  $A$  = 9.0 ml
- Volume of FAS consumed in blank titration =  $B$  = 15.0 ml.
- Volume of  $K_2Cr_2O_7$  consumed in satisfying COD in terms of FAS solution =  $(B-A)$  ml
- Normality of FAS solution =  $N_{FAS} = N/4 = 0.25 \text{ N}$

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

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#### Solution:

❖ Chemical Oxygen Demand (COD):

$$V_s \times N_{COD} = (B-A) \times N_{FAS}$$

$$N_{COD} = (B-A) N_{FAS} / V_s = ((15.0 - 9.0) \times 0.25) / 20 = 0.075N.$$

Chemical Oxygen Demand of sewage sample = COD = Normality of reaction mixture (sewage sample) in terms of COD x Equivalent weight of Oxygen x 1000 ppm

$$COD = N_{COD} \times 8 \times 1000 \text{ ppm.}$$

Therefore, COD = 0.075 x 8 x 1000 ppm.

❖ Chemical Oxygen Demand = 600 ppm

2. In COD experiment, 50ml of an effluent sample required 10ml of 0.2N  $K_2Cr_2O_7$  solution for oxidation. Calculate the COD of sewage sample.

#### Given:

- Volume of effluent sample = 'V<sub>s</sub>' = 50ml
- Normality of reaction mixture (effluent sample) in terms of COD = N<sub>COD</sub>
- Volume of  $K_2Cr_2O_7$  solution = V<sub>1</sub> = 10 ml.
- Normality of  $K_2Cr_2O_7$  solution = N<sub>1</sub> = 0.2N

#### Solution:

- ❖  $V_s \times N_{COD} = V_1 \times N_1$
- ❖  $N_{COD} = (V_1 \times N_1) / V_s$
- ❖  $N_{COD} = (10 \times 0.2) / 50 \text{ N}$

$$\diamond \quad \text{Normality of reaction mixture in terms of COD} = N_{COD} = 0.04N$$

- Chemical Oxygen Demand of effluent sample = COD = (Normality of reaction mixture in terms of COD x Equivalent weight of Oxygen x 1000) ppm

$$COD = N_{COD} \times 8 \times 1000 \text{ ppm.}$$

Therefore, COD = 0.04 x 8 x 1000 ppm.

❖ Chemical Oxygen Demand = 320 ppm.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

## REVERSE OSMOSIS

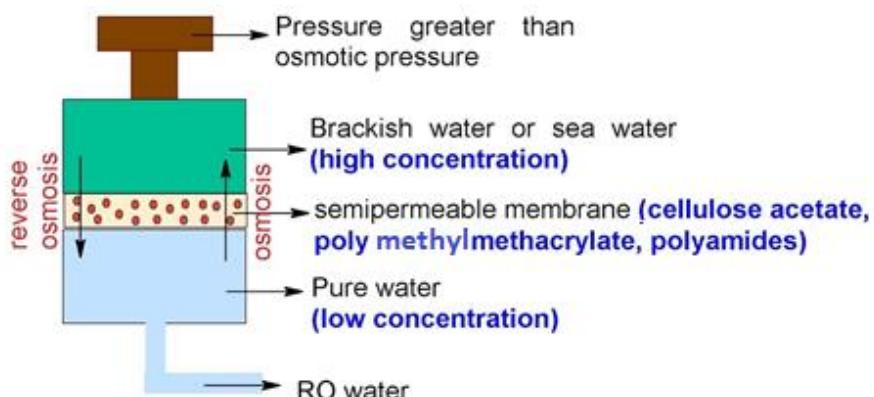
**Reverse osmosis (RO)** is a water purification process that uses a semi-permeable membrane to removes ions, unwanted molecules and larger particles from water.

**Principle:**

When two solutions of unequal concentrations are separated by a semipermeable membrane flow of solvent takes place from dilute to concentrate side due to osmosis. If however a hydrostatic pressure in excess of osmotic pressure is applied on the concentrated side, the solvent flow reverses. That is the solvent is forced to move from concentrated side to dilute side across the membrane. This is the principle of reverse osmosis.

Thus in reverse osmosis method, pure solvent (water) is separated from its contaminants rather than removing contaminants from water. This membrane filtration is also known as super filtration or hyper filtration or ultrafiltration.

**Procedure:**



### **REVERSE OSMOSIS PROCESS**

The process is carried out in a reverse osmosis cell. In this cell, the sea water to be desalinated is separated from fresh water through a semi permeable membrane. In this process, the pressure in excess of osmotic pressure is applied to the sea water to be treated to force its pure water out through the semi permeable membrane leaving behind the dissolved solids both ionic as well as non-ionic.

The membrane consists of very thin film of nylon or cellulose acetate supported between perforated plates. Recently, superior membranes made up of PMMA and polyamide polymers have been used.

As a result of reverse osmosis, fresh water moves down and can be collected from the bottom outlet of the cell.

## Department of Chemistry

### **ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY**

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#### **Advantages:**

- It is economical, compact and very simple.
- It has long life of 2 years.
- It is easy to replace the membrane 2 minutes thereby providing unlimited water supply.
- It can effectively eliminate a broad spectrum of contaminants, including inorganic salts (e.g., sodium, chloride), heavy metals and organic compounds (e.g., pesticides, pharmaceuticals)
- It can produce high-quality water. That is it produces purified water with low mineral content, suitable for various applications.
- Due to low capital cost, simplicity, low operating cost and high reliability, the reverse osmosis is gaining importance at present for converting sea water into drinking water and for obtaining water for very high pressure boilers.

#### **Applications:**

- Municipal drinking water: RO is widely used in municipal water treatment plants to provide clean drinking water for communities.
- Desalination: RO plays a crucial role in converting seawater into freshwater for regions facing water scarcity.
- Industrial processes: High-purity water is required in various industries like electronics manufacturing and pharmaceuticals, and RO is often employed for this purpose.
- Medical applications: In hemodialysis, RO is used to remove waste products from a patient's blood.

#### **Limitations:**

- Wastewater generation: RO produces a concentrated brine solution that needs proper disposal.
- Membrane replacement: RO membranes have a limited lifespan and require periodic replacement, adding to the operational cost.

#### **Note:**

Desalinated water is not fit for drinking purpose because it does not contain essential minerals required for maintaining proper good human health. So water obtained from Reverse Osmosis process is used only in oil rich water containing countries. The desalinated water is replenished with adequate amount of essential minerals to make that water fit for drinking purpose. The cost of such water is extra ordinarily high.

## Department of Chemistry

### ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY

## ELECTRODIALYSIS

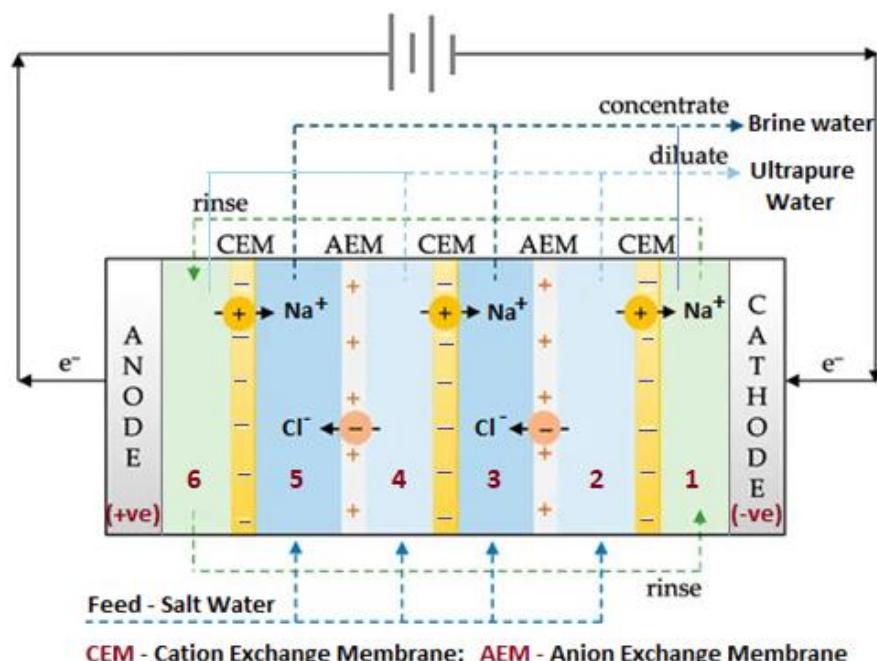
The process of decreasing the concentration of salts in saline water using ion selective membranes under the influence of applied emf is called Electrodialysis (ED). That is electrodialysis is an electrochemical water treatment process that utilizes electrical energy to remove salts and other ionic impurities from water.

### Principle:

- The electrodialysis involves a stack of alternating anion and cation exchange membranes placed between two electrodes (anode and cathode).
- When a direct current (DC) voltage is applied, cations (positively charged ions) migrate towards the negatively charged cathode through the cation exchange membranes & anions (negatively charged ions) move towards the positively charged anode through the anion exchange membranes. This selective movement of ions separates the feed solution containing the impurities into two streams:
  - ❖ Concentrate stream: Enriched with the removed ions.
  - ❖ Dilute stream: Partially demineralized water with lower salt content.

Thus in ED method, pure solvent (water) is separated from its salts ( $\text{Na}^+$  &  $\text{Cl}^-$  ions).

### Procedure:



## ELECTRODIALYSIS PROCESS

## Department of Chemistry

### **ENGINEERING CHEMISTRY, 24ECHB102 - UNIT 2 - CHAPTER 4: CHEMISTRY AND SUSTAINABILITY**

The process is carried out in an electrodialysis cell. It consists of two electrodes and ion exchange membranes which are permeable to either cation or anion. The anion exchange membrane contains positively charged functional groups such as  $RyN^+$  while cation exchange membrane contains negatively charged functional groups such as  $RCOO^-$ . The water to be treated is passed through the channels between the alternating membranes. A DC voltage is applied across the electrodes. Cations and anions selectively migrate through their respective membranes, driven by the electrical potential. The demineralized water exits as the dilute stream, while the concentrated stream containing the removed ions exits from another channel.

That is, as a result of electrodialysis process, the concentration of ions in alternate compartments such as 2, 4, 6, etc., decreases while it increases in alternate compartments such as 1, 3, 5, etc., Thus, water in the even number compartments becomes pure and is collected from the separate outlet of the electrodialysis cell. Similarly, the water in the odd number compartments becomes rich in saline salts and is collected from the separate outlet of the cell.

#### **Advantages:**

- It is economical, convenient and may be applied at room temperature.
- It is most compact in size and requires only electricity for operation.
- Environmentally friendly: Doesn't involve the use of harsh chemicals.
- Selective removal: Can target specific ions based on the chosen membranes.

#### **Applications:**

- Production of potable water and salts from sea water.
- Desalination of brackish water: ED is effective in removing salts from brackish water (water with higher salinity than freshwater but lower than seawater) for various applications like irrigation and industrial use.
- Food and beverage industry: Used to purify and concentrate food products like juices, syrups and dairy products.
- Chemical industry: Employed to recover valuable chemicals and separate ionic compounds in various processes.
- Pharmaceutical industry: Used to purify water for pharmaceutical applications.
- Demineralization of cheese whey and removal of tartaric acid in wine.

#### **Limitations:**

- Energy consumption: The process requires electrical energy to function.
- Membrane fouling: Mineral build-up on the membranes can reduce efficiency and require periodic cleaning.
- Limited effectiveness: Not suitable for removing non-ionic contaminants or organic matter.