MTT

60 marks
(10 – Six mark questions)
{No choice}

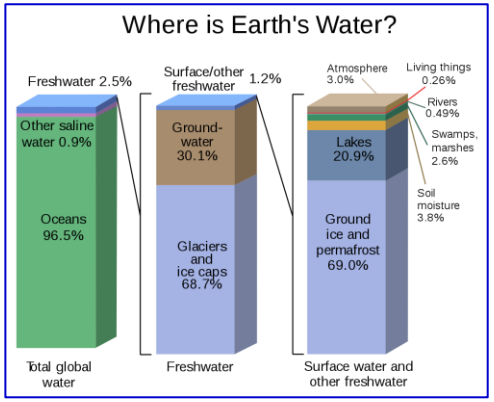
Module – 1

&

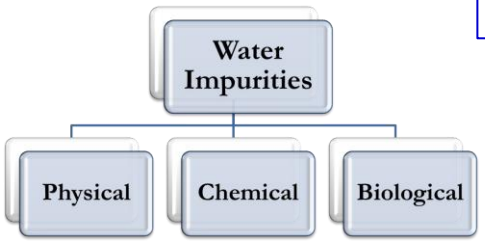
Module – 2

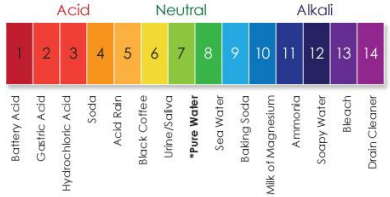
Module-1

Water Technology



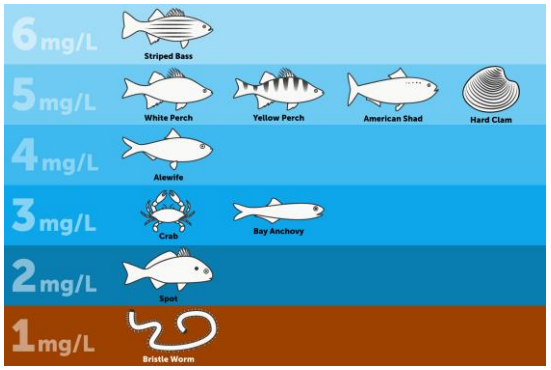
- **Water Resources**
- **Water Impurities**
  - Physical
  - Chemical
  - Biological
- **Water Quality**
  - pH
  - Dissolved Oxygen (DO)
  - Biological Oxygen Demand (BOD)
  - Chemical Oxygen Demand (COD)
  - Total Dissolved Solids (TDS)
  - Hardness

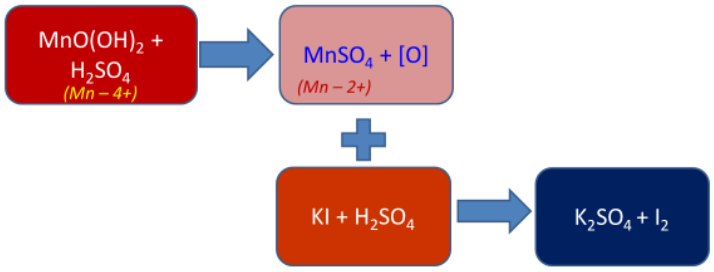




1. Dissolved Oxygen (DO)

- **Dissolved oxygen**
  - Amount of oxygen dissolved in a given quantity of water
- **Parameters affect DO**
  - ✓ Pressure
  - ✓ Aquatic plants
  - ✘ Temperature
  - ✘ Salinity
  - ✘ Dead plants
  - ✘ Chemically oxidizable impurities
- **Importance of DO**
- **DO Estimation**
  - Winkler's method





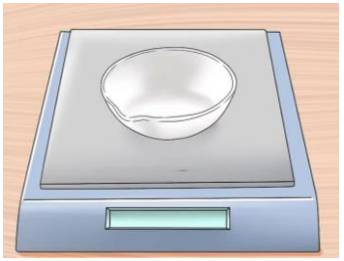
i) Mn^{4+} in sulphate form reacts with KI and liberates I_2 (Iodometric titration)

ii) **[DO] α [Mn^{4+}] α [I_2]**

(Sodium thiosulphate can be used to estimate the concentration of I_2 with Starch Indicator)

2. Total dissolved solids (TDS)

- **Total dissolved solids**
  - Remains in water after passing through ~2 μm filter
- **Sources of TDS**
  - Organic sources
  - Silt (find sand, clay, etc.)
  - Industrial waste
  - Inorganic materials such as calcium bicarbonates from rocks
- **TDS – Measurement**
  - Evaporation, drying and weighing
  - Conductivity
  - Gravimetric



3. Hardness of water

- **Hardness**
  - Characteristic of preventing lather formation with soap
  - Salts like chlorides, bicarbonates and sulfates of Ca^{2+}, Mg^{2+}, Fe^{2+} and other heavy metals

- **Types of Hardness**
  - Temporary hardness
    - Carbonate hardness
    - Alkaline hardness
    - Can be removed by boiling & filtration
  - Permanent hardness
    - Non-carbonate hardness
    - Non-alkaline hardness
    - Can be removed by chemicals like lime and soda
- **Unit of Hardness**
  - ppm

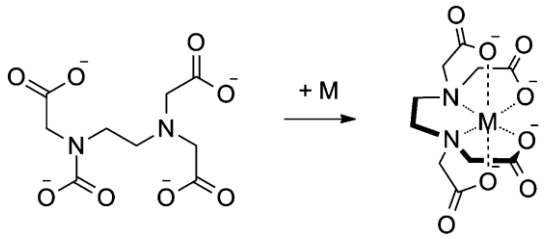
Hardness of water

- **$CaCO_3$ equivalence – Numerical problems**

Hardness

$$\text{Equivalent of } CaCO_3 = \text{Mass of hardness producing substance} \times \frac{\text{Molecular weight of } CaCO_3}{\text{Molecular weight of hardness producing substance}}$$

- **Estimation of Hardness**
  - EDTA titration method
    - EBT indicator



$$Ca^{2+}/Mg^{2+} + \text{EBT} \xrightarrow{\text{pH 9-10}} Ca^{2+}/Mg^{2+} - \text{EBT}$$

(unstable complex – wine red)

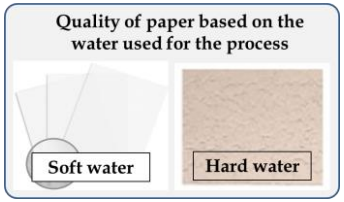
$$Ca^{2+}/Mg^{2+} - \text{EBT} + \text{EDTA} \xrightarrow{\text{pH 9-10}} Ca^{2+}/Mg^{2+} - \text{EDTA} + \text{EBT}$$

(Stable complex - Steel blue)

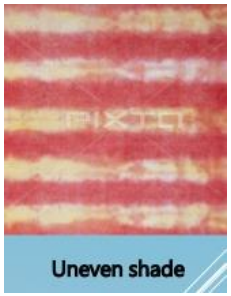
- **Numerical problems – Hardness**
  - Total, Permanent and Temporary hardness

Hardness of water

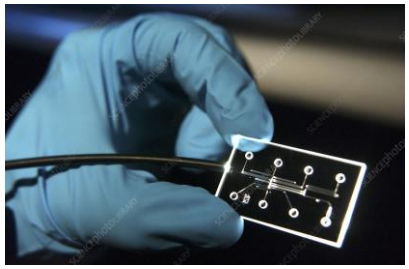
- **Disadvantage of Hard Water**
  - **In Domestic**
    - Washing & bathing
    - Cooking
    - Drinking
  - **In Industries**
    - Paper industry
    - Textile industry
    - Sugar industry
    - In concrete making
    - In steam generation boiler



Sugar crystals



- **In steam generation boiler**
  - **Sludge and Scale formation**
    - **Sludges** : If loose & slimy precipitate formed
    - **Scale** : If sticky, hard & adherent coat formed
      - Prevention of scale (Internal & External conditioning)
  - **Priming & Foaming**
    - **Priming** : Wet steam
    - **Foaming** : Persistent foam/bubbles – don't break easily
  - **Caustic embrittlement**
    - NaOH – Excess use of soda-lime for softening process
  - **Boiler corrosion**
    - Dissolved oxygen
    - Dissolved carbon dioxide
    - Acids from dissolved salts
- **Modern methods of water analysis**
  - ✓ Lab-on-chip



Units of Hardness

- Both temporary and permanent hardness are expressed in mg/L (ppm) as equivalent of $CaCO_3$
- The choice of $CaCO_3$ is due to the fact that
  - It is the most insoluble salt in water
  - Besides, its molecular weight is 100 and equivalent weight is 50

Hardness

$$\text{Equivalent of } CaCO_3 = \text{Mass of hardness producing substance} \times \frac{\text{Molecular weight of } CaCO_3}{\text{Molecular weight of hardness producing substance}}$$

1 Examples of hardness calculations

A sample hard water contains,

8.1 mg/L $Ca(HCO_3)_2$; 7.5 mg/L $Mg(HCO_3)_2$; 13.6 mg/L $CaSO_4$; 12.0 mg/L $MgSO_4$ and 2.0 mg/L $MgCl_2$.

To calculate the hardness and express in $CaCO_3$ equivalents:

Constituent	Multiplication factor	$CaCO_3$ equivalents	Hardness
$Ca(HCO_3)_2$= 8.1 mg/L	100/162	8.1 x 100/162 = 5.0 mg/L	Temporary
$Mg(HCO_3)_2$ = 7.5 mg/L	100/146	7.5 x 100/146 = 5.14 mg/L	
$CaSO_4$= 13.6 mg/L	100/136	13.6 x 100/136 = 5.0 mg/L	Permanent
$MgSO_4$= 12.0 mg/L	100/120	12.0 x 100/120 =10.0 mg/L	
$MgCl_2$ = 2.0 mg/L	100/95	2.0 x 100/95 = 2.11 mg/L	

1 Examples of hardness calculations

Temporary hardness of water

due to $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ = 5.0 + 5.14

= **10.14 mg/L or ppm $CaCO_3$ eq.**

Permanent hardness of water

due to $CaSO_4$, $MgSO_4$ and $MgCl_2$ = 5.0 + 10.0 + 2.11

= **17.11 mg/L or ppm $CaCO_3$ eq.**

Total hardness of water = 10.14 + 17.11

= **27.25 mg/L or ppm $CaCO_3$ eq.**

2 Examples of hardness calculations

Calculate the temporary and total hardness of a water sample containing

$Mg(HCO_3)_2$= 73mg/L

$Ca(HCO_3)_2$= 162mg/L

$MgCl_2$= 95mg/L

$CaSO_4$=136mg/L

Molecular weight

$Mg(HCO_3)_2$= 146

$Ca(HCO_3)_2$= 162

$MgCl_2$= 95

$CaSO_4$=136

2 Examples of hardness calculations

Solution: calculation of $CaCO_3$ equivalents:

Constituent	Multiplication factor	$CaCO_3$ equivalent
$Mg(HCO_3)_2$= 73mg/L	100/146	73X100/146= 50mg/L
$Ca(HCO_3)_2$= 162mg/L	100/162	162X100/162=100mg/L
$MgCl_2$= 95mg/L	100/95	95X100/95= 100mg/L
$CaSO_4$=136mg/L	100/136	136X100/136= 100mg/L

∴ Temporary hardness of water due to $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ =

=100 + 50=150mg/L or ppm.

Total hardness of water= 50+100+100+100=350 mg/L or ppm.

Formula

- Total hardness of sample hard water = $\left(\frac{V_2}{V_1}\right) \times 1000$ mg/L
- Permanent hardness = $\left(\frac{V_3}{V_1}\right) \times 1000$ mg/L
- Temporary Hardness = Total Hardness – Permanent hardness

Provided the volume of standard hard water, sample hard water and boiled & filtered sample hard water are same

Numerical problems in hardness determination by EDTA

(1) The standard hard water is prepared by dissolving 1 g of $CaCO_3$ in HCl and the solution is made up to 1000 mL with deionized water. 50 mL of the prepared solution requires 20 mL of EDTA solution for titration. 50 mL of sample water requires 15 mL of EDTA solution and after boiling and filtering 50 mL of the solution requires 10 mL of EDTA. Calculate the total, carbonate and non-carbonate hardness of the water sample.

Numerical problems in hardness determination by EDTA

Solution

V_1 = **20 mL** (volume of standard hard water = **50 mL**)
V_2 = **15 mL** (volume of sample hard water = **50 mL**)
V_3 = **10 mL** (volume of boiled sample hard water = **50 mL**)

Total hardness of sample hard water = $\left(\frac{V_2}{V_1}\right) \times 1000$ mg/L

= (15/20) x 1000 = 750 ppm

Permanent hardness = $\left(\frac{V_3}{V_1}\right) \times 1000$ mg/L

= (10/20) x 1000 = 500 ppm

Temporary Hardness = Total Hardness – Permanent hardness

= 750 - 500 = 250 ppm

Formula

- Total hardness of sample hard water = $\left(\frac{x}{V_1}\right) \times \left(\frac{V_2}{y}\right) \times 1000$ mg/L
- Permanent hardness = $\left(\frac{x}{V_1}\right) \times \left(\frac{V_3}{z}\right) \times 1000$ mg/L
- Temporary Hardness = Total Hardness – Permanent hardness

- x = Volume of standard hard water used for EDTA standardisation
- y = Volume of sample hard water used
- z = Volume of boiled & filtered sample hard water used

If the volume of standard hard water, sample hard water and boiled & filtered sample hard water are different

Numerical problems in hardness determination by EDTA

(2) 20 ml of std water containing 1 g/L of pure $CaCO_3$ per liter consumed 25 ml of EDTA. 100 ml of water sample consumed 18 ml of EDTA using EBT as indicator. While same water sample after boiling requires 12 ml of EDTA for 100 mL boiled water. Calculate carbonate and non-carbonate hardness of water.

Numerical problems in hardness determination by EDTA

Solution

V_1 = **25 mL** (volume of standard hard water = **20 mL**)
V_2 = **18 mL** (volume of sample hard water = **100 mL**)
V_3 = **12 mL** (volume of boiled sample hard water = **100 mL**)

Total hardness of sample hard water $= \left(\frac{20}{V_1}\right) \times \left(\frac{V_2}{100}\right) \times 1000$ mg/L

$= \left(\frac{20}{25}\right) \times \left(\frac{18}{100}\right) \times 1000 = 144$ ppm

Permanent hardness $= \left(\frac{20}{V_1}\right) \times \left(\frac{V_3}{100}\right) \times 1000$ mg/L

$= \left(\frac{20}{25}\right) \times \left(\frac{12}{100}\right) \times 1000 = 96$ ppm

Temporary Hardness = Total Hardness – Permanent hardness
= 144 - 96 = 48 ppm

Numerical problems in hardness determination by EDTA

(4) 0.5 g of $CaCO_3$ was dissolved in HCl and the solution made up to 1000 mL with distilled water. 50 mL of the solution required 50 mL of EDTA solution for titration. 50 mL of hard water sample required 18 mL of EDTA and after boiling and filtering required 10 mL of EDTA solution. Calculate each type of hardness of water.

0.5 g of $CaCO_3$ was dissolved in HCl and the solution made up to 1 L with distilled water.

1 L of standard hard water contains 0.5 g of $CaCO_3$

1000 mL of standard hard water contains 500 mg of $CaCO_3$

1 mL of standard hard water contains 0.5 mg of $CaCO_3$

Titration - I

50 mL of the solution required 50 mL of EDTA solution for titration. (V_1 = 50 mL)

50 mL of EDTA = 50 mL of standard hard water

= 50 x 0.5 mg of $CaCO_3$

= 25 mg of $CaCO_3$

1 mL of EDTA = 25/50 = **0.5 mg of $CaCO_3$**

Titration - II

50 mL of hard water sample required 18 mL of EDTA (V_2 = 18 mL)

1000 mL of sample hard water = $0.5 \times \left(\frac{V_2}{50}\right) \times 1000$ mg/L

= $0.5 \times \left(\frac{18}{50}\right) \times 1000$ mg/L

Total hardness = **180 ppm $CaCO_3$ eq.**

Titration - III

50 mL of hard water sample after boiling and filtering required 10 mL of EDTA solution (V_3 = 10 mL)

1000 mL of sample hard water = $0.5 \times \left(\frac{V_3}{50}\right) \times 1000$ mg/L

= $0.5 \times \left(\frac{10}{50}\right) \times 1000$ mg/L

Permanent hardness = **100 ppm $CaCO_3$ eq.**

Temporary hardness = Total hardness – Permanent hardness

= 180 – 100 = **80 ppm $CaCO_3$ eq.**