WATER TECHNOLOGY
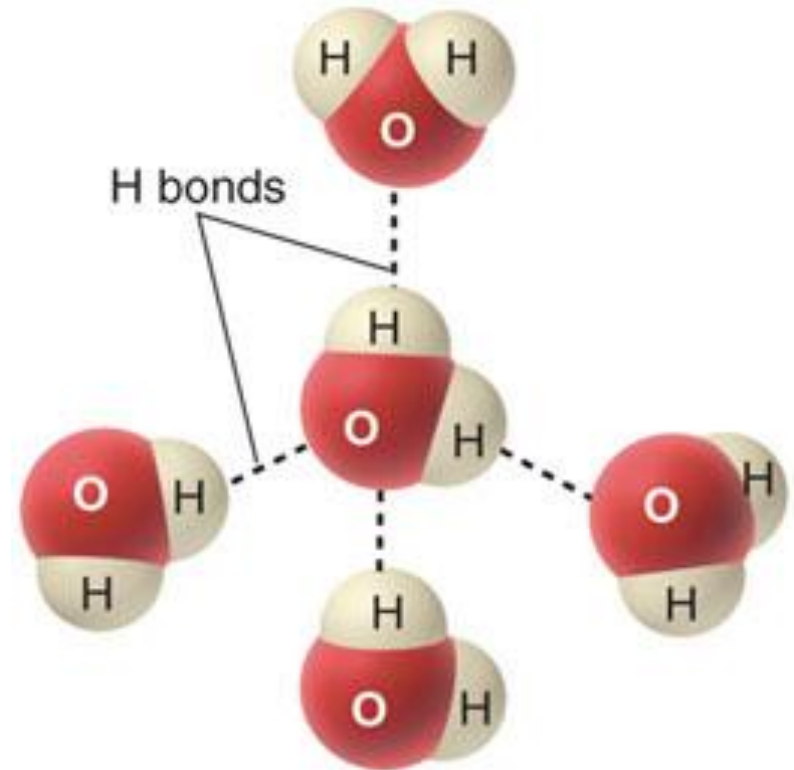
- **Introduction to water technology**

- **Chemistry of water**

- **Specifications of drinking water**

- **Source of impurities in water and types of impurities.**

- **Universal Solvent**

- **Polar Molecule**

- **High Latent Heat**

- **Hydrogen bonding**

- **High Surface Tension**

Parameter	Values (ppm) except pH
pH	6.5 - 8.5
Hardness	300
Chloride	250
DO	5
Nitrate	50
Turbidity	5
Fluoride	1.5
TDS	500

https://www.youtube.com/watch?v=LDLjKlBroUA

- Suspended Impurities

- Dissolved Impurities

- Colloidal Impurities

- Biological Impurities

- **Water analysis – types and units of hardness**

- **Estimation of hardness by EDTA method.**

- **Numericals**

- Hardness

- Alkalinity

- Chlorides

- Dissolved oxygen

- Soap consuming capacity of water sample

- Due to dissolved salts of Calcium and Magnesium

- Expressed in terms of ppm of $CaCO_3$

- $CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$

$$2C_{17}H_{35}COONa + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2Ca \downarrow + 2NaCl$$

Sodium stearate   Curd like ppt

- Also known as Carbonate or alkaline hardness

- Due to presence of $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$

- Temporary Hardness can be removed by boiling hard water

$$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2\downarrow + 2CO_2\uparrow$$

$$Ca(HCO_3)_2 \longrightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$$

Permanent Hardness

- **Also known as non carbonate or non alkaline hardness**

- **Due to Chlorides, Nitrates & Sulphates of Ca & Mg**

- **Cannot be removed by boiling**

**Total hardness = Temporary Hardness + Permanent Hardness**

Determination of Hardness by EDTA Method: Complexometric Titration

- Complexometric titrations are particularly useful for the determination metal ions concentration in solution. An indicator capable of producing an unambiguous color change is usually used to detect the end-point of the titration.

- Chelating agent used is

- EDTA -Ethylene Diamine TetraAcetic Acid

- It is a hexadentate ligand

- Water is titrated against a standard solution of Na_2EDTA which is preferred as it is more soluble in water

(a)

(b)
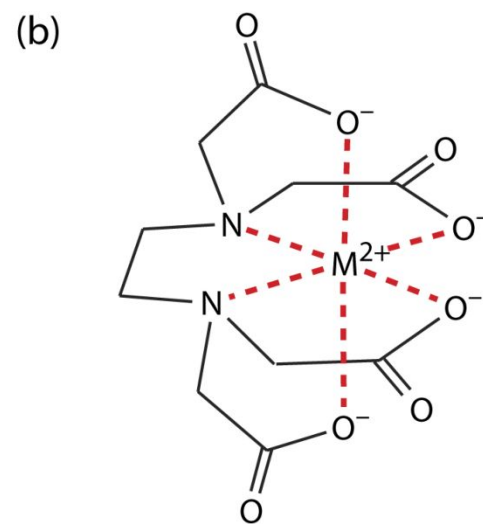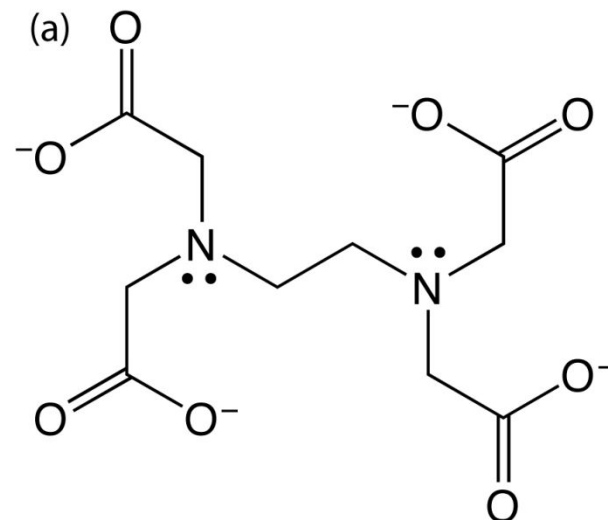
Determination of Hardness by EDTA Method

- Eriochrome Black T is used as the indicator

- pH 10 is maintained by Buffer (NH_4Cl + NH_4OH)

- Hardness = B.R x Molarity of EDTA x100 x 1000 / V

- B.R=Burette reading=Volume of EDTA solution

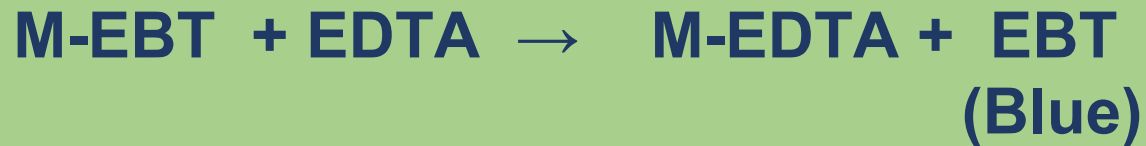- V is volume of water sample used for titration
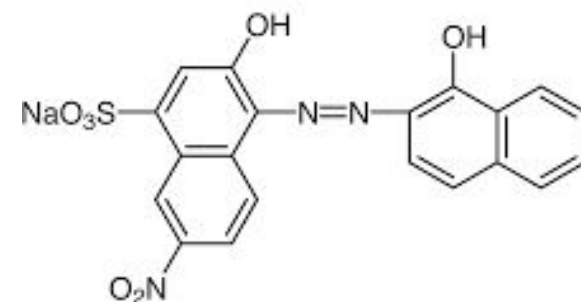
Procedure

Part-A: Standardization of Na_2EDTA by std. $ZnSO_4$ solution

Part-B: Determination of total hardness of water sample using Std. Na_2EDTA

$$M^{2+} + EBT \rightarrow M\text{-}EBT + 2H^+$$
Wine red

$$M\text{-}EBT + EDTA \rightarrow M\text{-}EDTA + EBT$$
(Blue)

Calculations

- Metal: EDTA is 1: 1 complex

- 1 mole of EDTA complexes with 1 mole Ca^{2+}/Mg^{2+} = 1 mole $CaCO_3$

- 1 mole of EDTA = 100 g of $CaCO_3$

- 1000 ml of 1M EDTA= 100 g of $CaCO_3$

- 1 ml of 1M EDTA = 100 mg of $CaCO_3$

- B.R. '**Y**' (volume of EDTA)ml of '**M**' M EDTA= 'Y' x 'M' x 100 mg of $CaCO_3$

- Volume of water sample= **V** ml

- For 1000 ml of water,

- **Hardness = Volume of EDTA x Molarity of EDTA x100 x1000**

-

- **Volume of water (V ml)**

1. **20 ml** standard hard water (containing 14 g $CaCO_3$ per lit.) required **22 ml** EDTA for the end point. **100 ml** of water sample required 15 ml EDTA solution. 100 ml of the same sample after boiling required 10 ml of EDTA solution Calculate carbonate(temporary hardness) and non-carbonate hardness(permanent hardness) of water.

Molarity of $CaCO_3$ = no. of moles of $CaCO_3$/ volume of solution

No. of moles = given weight of $CaCO_3$/Molecular weight of $CaCO_3$

= 0.14

Molarity of $CaCO_3$ = 0.14

M1 V1 = M2 V2

0.14 x 20 = M2 x 22 , M2 = 0.13

- **Total Hardness= 15 x 0.13 x 100 x 1000   = 1950 ppm**

- **   100**

- **Permanent Hardness = 10 x 0.13 x 100 x 1000   = 1300 ppm**

- **   100**

- **Temporary = Total – Permanent**
- **   = 1950 -1300 ppm**
- **   = 650 ppm**

2. Calculate temporary hardness, total hardness and permanent hardness in terms of $CaCO_3$ for sample with composition.

a) $Ca(HCO_3)_2$ = 6.4 mg/L

b) $Mg(HCO_3)_2$ = 8.2 mg/L

c) $MgSO_4$ = 5.6 mg/L

d) $MgCl_2$ = 4.2 mg/L

e) $CaSO_4$ = 12.3 mg/L

f) Na_2SO_4 = 6.5 mg/L

$$CaCO_3 \text{ equivalent of a substance 'X'} = \frac{\text{Amount of X (mg) x Eq. wt. of } CaCO_3}{\text{Eq. wt. of X}}$$

$Ca(HCO_3)_2$ = 3.95 mg/L

$Mg(HCO_3)_2$ = 5.62 mg/L

MgCl2 = 4.42 mg/L

$CaSO_4$ = 9.04 mg/L   MgSO4 = 4.67 mg/L

- Temporary Hardness = 3.95 + 5.62 = 9.57 ppm
- Permanent Hardness = 4.42+9.04+ 4.67= 18.13 ppm
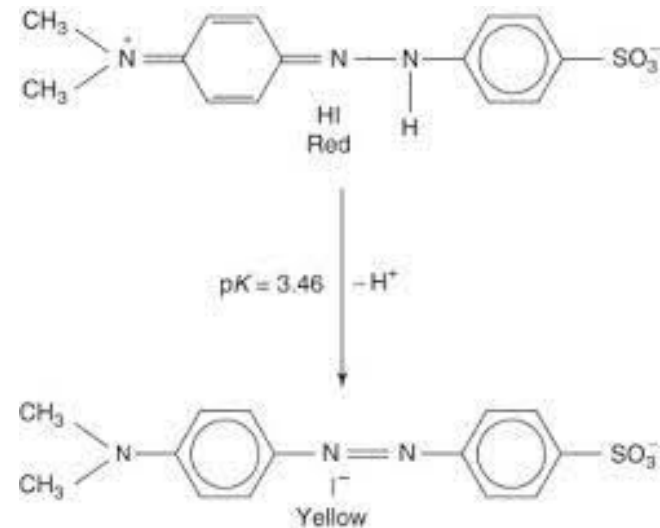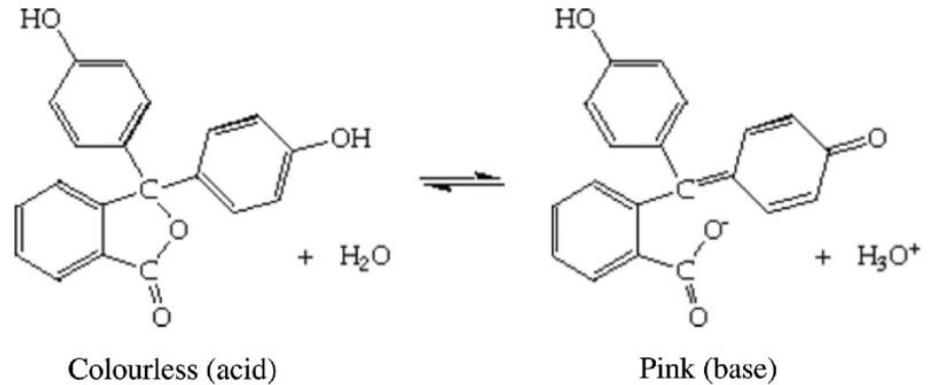- Total hardness = 27.7 ppm

- **Sources of alkalinity and its volumetric estimation**

- **Sources of chlorides**

- **Mohr's method for determination of chlorides.**

- **Numericals**

- Alkalinity is a measure of the water's ability to neutralize acidity

- An alkalinity test measures the level of bicarbonates, carbonates, and hydroxides in water and test results are generally expressed as "ppm of calcium carbonate $(CaCO_3)$"

- Fresh water usually has 20-200 mg/L levels of alkalinity.

- A total alkalinity level of 100-200 mg/L can stabilize the pH level in a stream.

- Determined by an acid-base titration

- Phenolphthalein And Methyl Orange are used as indicators

- **Only HO$^-$**

- **Only CO$_3^{2-}$**

- **Only HCO$_3^-$**

- **OH$^-$ & CO$_3^{2-}$ together**

- **CO$_3^{2-}$ & HCO$_3^-$ together**

Colourless (acid)   Pink (base)

HI Red

$pK = 3.46$ $-H^+$

Yellow

21

P

$$OH^- \;+\; H^+ \;\rightarrow\; H_2O$$

$$CO_3^{2-} \;+\; H^+ \;\rightarrow\; HCO_3^-$$

$$HCO_3^- \;+\; H^+ \;\rightarrow\; H_2O + CO_2\uparrow$$

M

- **Phenolphthalein alkalinity (P)**

  $P = (V_{1acid} \times N_{acid} \times 50 \times 1000) / V_{water}$ ppm of $CaCO_3$ equivalents.

- **Methyl orange alkalinity (M) OR Total alkalinity**

  $M = (V_{2acid} \times N_{acid} \times 50 \times 1000) / V_{water}$ ppm of $CaCO_3$ equivalents

- 1 g equivalent of HCl = 1 g equivalent of $CaCO_3$

- 1000 ml of 1N HCl = 50 g of $CaCO_3$

-   0.0

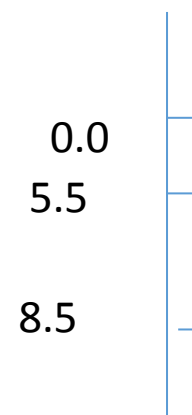-   5.5

- 1 ml of 1N HCl = 50 mg of $CaCO_3$

-   8.5

-

- V1 ml of 'Y' N HCl = 50 x V_1 x Y mg of $CaCO_3$
-                                    = Z mg of $CaCO_3$

For Volume of water analysed = V ml , Z is the quantity

For 1000 ml

Phenolphthalein Alkalinity = V_1 x Y x 50 x 1000   mg/L

$$\overline{\qquad\qquad V \qquad\qquad}$$

Methyl Orange/Total Alkalinity = V_2 x Y x 50 x 1000   mg/L

$$\overline{\qquad\qquad V \qquad\qquad}$$

Alkalinity Interpretation

Relation between P & M	OH^-	CO_3^{2-}	HCO_3^-
P = 0	0	0	M
P = M	P/M	0	0
P=1/2 M	0	2P	0
P>1/2M	2P-M	2(M-P)	0
P<1/2M	0	2P	M-2P

- 50 ml water sample requires 4.5 ml of N/50 HCl upto phenolphthalein end point and another 6 ml upto methyl orange end point, compute the individual alkalinity of water.

- P = 4.5 x 0.02 x 1000 = 90 ppm

- M= 10.5 x 20 =210 ppm

- Water sample is not alkaline to phenolphthalein. 100ml of sample on titration with N/50 HCl required 17.5 ml to get methyl orange end point. Compute alkalinity result.

- **Chloride ions come into solution in water in underground aquifers, geological formations that contain groundwater.**

- **Chloride ion concentrations of between 1 and 100 ppm (parts per million) are normal in freshwater.**

- **Chloride ion concentration is determined by <u>Mohr's Method</u> which is a titration of <u>water sample with $AgNO_3$</u> in neutral or slightly alkaline pH in presence of <u>potassium chromate as the indicator</u>.**

Mohr's Method

- **This is called Argentometric Titration.**

- **Highly alkaline pH leads to formation of Silver Hydroxide (AgOH)**

- **At Low pH Chromate may transformed into dichromate leading to inaccurate result (CrO_4^{2-} $\implies$ $Cr_2O_7^{2-}$)**

- **At the start, chloride ions react with silver ions forming white ppt of Silver Chloride**

$$Ag^+ \ + \ Cl^- \longrightarrow AgCl\downarrow$$

❖   **White ppt**

- **After all chloride are used up Ag^+ reacts with chromate ion (from the indicator) forming brick red precipitate.**

$$Ag^+ \ + \ CrO_4^{2-} \longrightarrow Ag_2CrO_4 \downarrow$$

Brick-red ppt

1 g equivalent of $AgNO_3$ = 1 g equivalent of Cl^-

1000 ml 1N $AgNO_3$ = 35.5 g Cl^-

amount of chloride = $N_1 \times V_1 / V_2 \times 35.5 \times 1000$ mg/L

N_1 = Normality of $AgNO_3$

V_1 = Volume of $AgNO_3$

V_2 = Volume of water sample

- Chloride ion concentration above 250 ppm is not acceptable

- **Dissolved oxygen**

- **Effects of DO level on drinking water and water for industrial use**

- **Estimation of DO by Winkler method**

- **Dissolved Oxygen** is the amount of gaseous **oxygen** (O_2) **dissolved** in the water.

- **Oxygen** enters the water by direct absorption from the atmosphere, by rapid movement, or as a by product of plant photosynthesis. Water temperature, salt concentration can affect **dissolved oxygen** levels.

- **Measurement gives idea about status of water system (Aerobic /Anaerobic)**

- **Indicator of water pollution**

- **DO level can give idea about survival of aquatic life**

- **DO is important factor causing corrosion of boiler metal**

- **Possibility of aerobic biological processes for transforming biodegradable organic contaminants**

https://www.youtube.com/watch?v=oVWElAzd75a

- **O$_2$ Fixation**

$$MnSO_4 + 2KOH \longrightarrow Mn(OH)_{2\downarrow} + K_2SO_4 \quad (\text{White})$$

- **Conversion Mn (II) to Mn(IV) forming Brown ppt of Basic Manganic oxide**

$$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_{2\downarrow} \quad (\text{Brown ppt})$$

- **Conversion of Mn (IV) to Mn(II) on Acidification**

$$MnO(OH)_2 + H_2SO_4 \longrightarrow MnSO_4 + 2H_2O + (O)$$

33

Oxidation of KI into I_2 by Nascent oxygen

$$2KI + H_2SO_4 + O \longrightarrow K_2SO_4 + H_2O + I_2$$

Titration of liberated iodine with sodium thiosulphate using starch indicator

$$I_2 + 2Na_2S_2O_3 \longrightarrow Na_2S_4O_6 \downarrow + 2NaI$$

1

**Add
1 mL
MnSO$_4$ Soln.
and
1 mL
Alkali-iodide-azide
Reagent**

**Carefully
Collect
Sample
In 300 mL
BOD Bottle**

**Yellow
To
Brown
Floc,
D.O. Present**

**White
Floc,
No D.O.**

2

**Mix By
Inverting
and
Allow To
Settle**

3

**Repeat
Mixing
and
Settling**

4

**Add
1 mL
H$_2$SO$_4$
and
Mix**

35
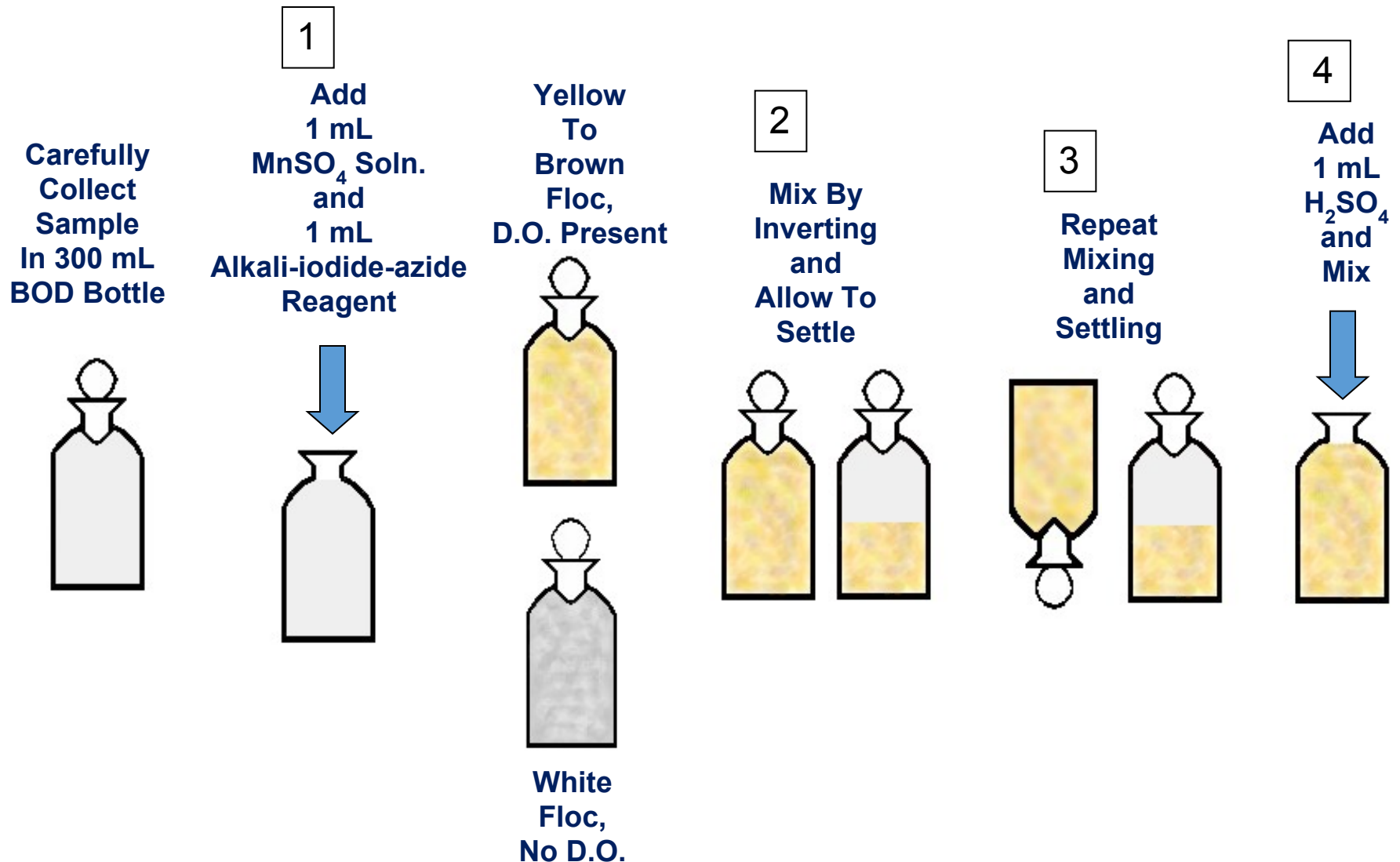
Titration of Iodine Solution

A
Pour 200 mL sample Into Flask
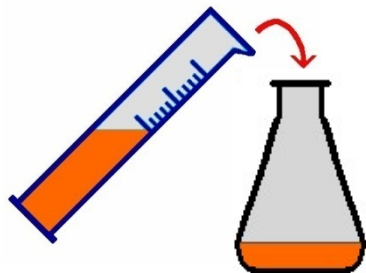
B
Titrate With Sodium thiosulphate

Reddish-Brown
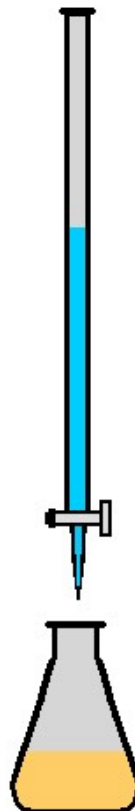
Pale Yellow

C
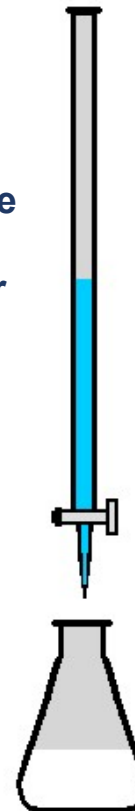Add Starch Indicator
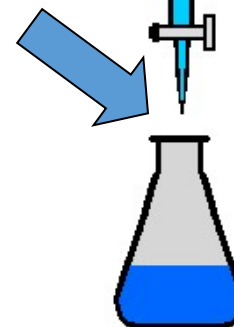
Blue

D
Titrate to Clear

Clear

Nitrate ion interference may be avoided by adding sodium azide

Dissolved Oxygen = $\dfrac{V_{Na2S2O3} \times N_{Na2S2O3} \times 8 \times 1000}{\text{Volume of water}}$ **mg/L**

1 g eq. of $Na_2S_2O_3.5H_2O$ = 1 g eq. of oxygen

1000 ml of 1N $Na_2S_2O_3.5H_2O$ = 8 g of oxygen

1 ml of 1N $Na_2S_2O_3.5H_2O$ = 8 mg of oxygen

Volume of water taken for titration= V ml

'X' ml of 'Y' N $Na_2S_2O_3.5H_2O$ = 8 x X x Y mg of oxygen

For 1000 ml = $\dfrac{8 \times X \times Y \times 1000}{V}$

Lecture - V

- Quality requirements of boiler feed water

- External treatments

- Ill effects of hard water in boilers

- Carryover(priming and foaming)

- Caustic embrittlement

- Boiler corrosion

- Sludge and scale formation

Water expands 1600 times as it evaporates to form steam at atmospheric pressure.

The steam is capable of carrying large quantities of heat.

These unique properties of water make it an ideal raw material for heating and power generating processes.

All natural waters contain varying amounts of dissolved and suspended matter and dissolved gases the amount of minerals dissolved in water varies from 30 g/l in sea water to anything from 0.005 to 1500 mg/l in fresh water supplies.

Since water impurities cause

boiler problems, careful consideration

must be given to the quality

of the water used for generating steam

Ill Effects of Boiler Feed Water

A) Priming & foaming (carryover)

B) Caustic embrittlement

C) Boiler Corrosion

D) Scales & Sludges

Priming is the carryover of varying amounts of droplets of water in the steam (foam and mist), which lowers the energy efficiency of the steam and leads to the deposit of salt crystals   on the super heaters and in the turbines.

.

Causes

- Very high level of boiler feed water

- Presence of excessive foam

- High speed of steam generation

- Faulty boiler design.

- Avoiding rapid changes in steaming rate
- Maintaining optimum level of water

- Better Boiler Design

- Removing impurities from water

Formation of continuous foam or bubbles on the surface of water resulting in wet steam formation.

Causes:

- High conc. of dissolved salts in boiler feed water

- Presence of oil droplets and alkalies

- Presence of finely dispersed suspended material

- Violent agitation of boiler feed water

- Use of antifoaming agents such as certain alcohols like cetostearyl alcohol, oils like castor oil.

- Removal of oil and greases using sodium aluminates

- Removal of silica using ferrous sulphate

- By using soft water

Disadvantages of priming and foaming

- Actual height of water column cannot be judged well due to foaming

- Because of priming, the salts present in the droplets enter in different parts of machineries.

- The dissolved salts in droplet of wet steam get deposited on evaporation of water

- Foaming causes wet steam formation

- **Boiler material gets brittle due to exposure to caustic solution under high pressure and high temperature condition.**

- **Cause**

- As water evaporates in the boiler, the concentration of sodium carbonate increases in the boiler. Sodium carbonate is used in softening of water by lime soda process, due to this some sodium carbonate maybe left behind in the water. As the concentration of sodium carbonate increases, it undergoes hydrolysis to form sodium hydroxide.

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2 \uparrow$$

$$2Fe + 2NaOH + O_2 \longrightarrow 2NaFeO_2 + H_2 \uparrow$$
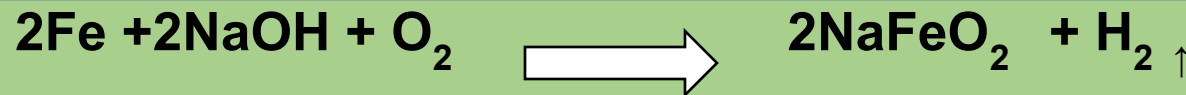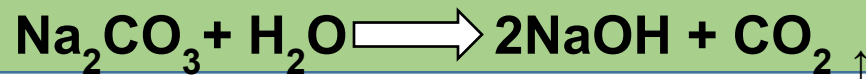
Galvanic cell or Concentration cell formation

- The presence of sodium hydroxide makes the water alkaline. This alkaline water enters minute cracks present in the inner walls of the boiler by capillary action.

- Inside the cracks, the water evaporates and the amount of hydroxide keeps increasing progressively.

- The concentrated area with high stress works as anode and diluted area works as cathode.

- At anode, sodium hydroxide attacks the surrounding material and then dissolves the iron of the boiler as sodium ferrate forming rust.

- This causes embrittlement of boiler parts like rivets, bends and joints, which are under stress.

- Use of materials that do not crack when used in given environments.
- Avoiding alkali where necessary or adjusting pH.
- Replacing sodium carbonate with sodium sulphate as softening reagents.
- Adding lignin, tannin or sodium sulphate that blocks hairline cracks as well as preventing infiltration of sodium hydroxide into those areas.

1.Dissolved oxygen

- $2Fe + 2H_2O + O_2 \longrightarrow 2Fe(OH)_2\downarrow$

- $2Fe(OH)_2 + 1/2O_2 \longrightarrow Fe_2O_3.2H_2O$
  (Rust)
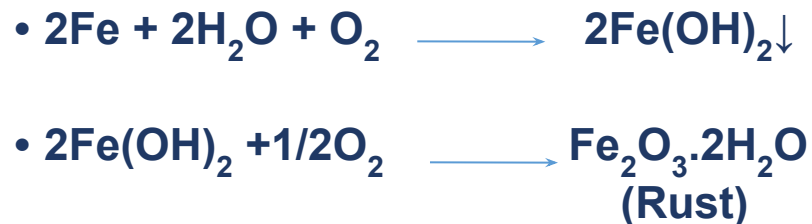
Removal of oxygen from water
Chemical deaeration

- $Na_2SO_3 + 1/2O_2 \longrightarrow Na_2SO_4$

- $N_2H_4 + O_2 \longrightarrow N_2\uparrow + 2H_2O$

2.Dissolved CO$_2$
$CO_2 + H_2O \longrightarrow H_2CO_3$

Removal

$CO_2 + NH_3 \longrightarrow (NH_4)_2CO_3$

III) Hydrolysis of salts

- $MgCl_2 + 2H_2O \longrightarrow 2Mg(OH)_2 + 2HCl$

- $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

- $FeCl_2 + 2H_2O \longrightarrow Fe(OH)_2 + 2HCl$
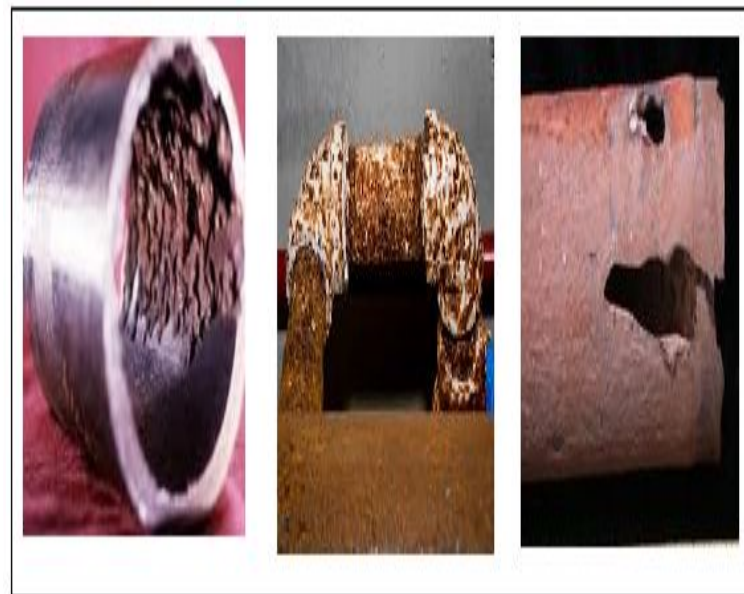
Disadvantages

- **Reducing the life of boiler**

- **Leakage of joints and rivets**

- **Increased cost of repairs & maintenance**

Scales & Sludges formation

- **Boiler scale is caused by impurities being precipitated out of the water directly on heat transfer surfaces or by suspended matter in water settling out on the metal and becoming hard and adherent.**

- **Evaporation in a boiler causes impurities to concentrate.**

- **This interferes with heat transfers and may cause hot spots. Leading to local overheating. Scaling mechanism is the exceeding of the solubility limits of mineral substances due to elevated temperature.**

- **The less heat they conduct, the more dangerous they are.**

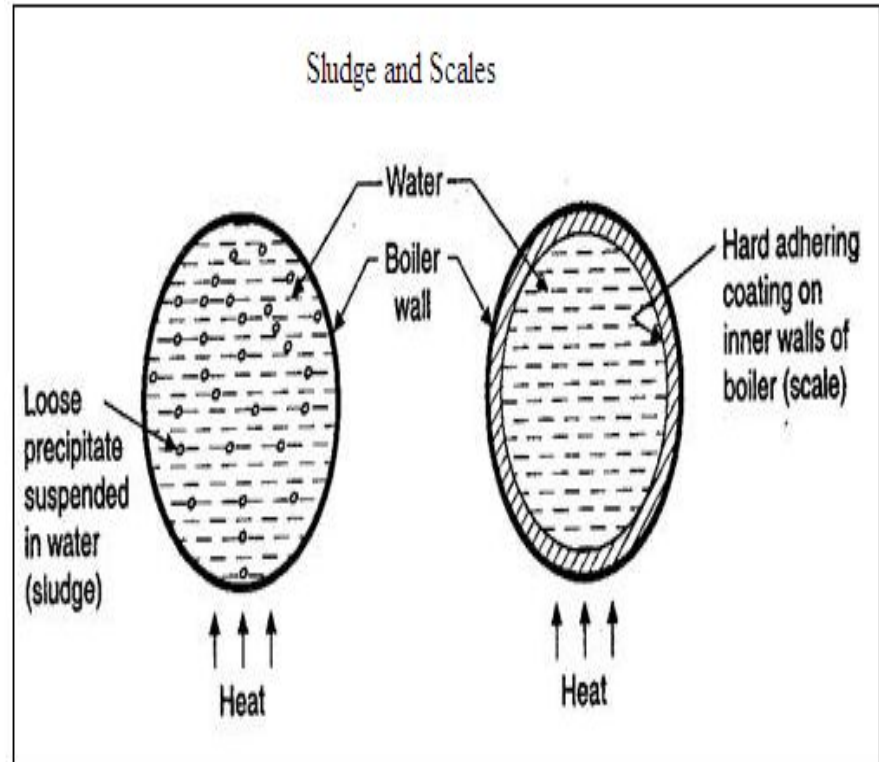 **Scales are formed due to the presence of $CaSO_4$, $Mg(OH)_2$, $MgCl_2$, $CaCO_3$, silicates of Ca & Mg.**
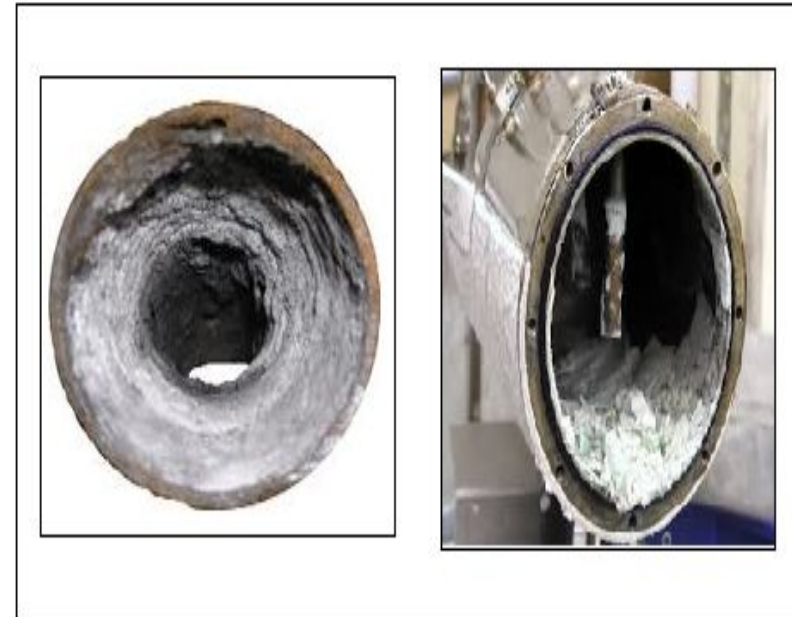
Causes -

i) **Thermal decomposition of bicarbonates of Ca & Mg**

ii) **Hydrolysis of magnesium salts**

iii) **Presence of silica**

iv) **Decreased solubilities of $CaSO_4$ at high temperature**

- **Wastage of Fuel**

- **Over heating of boiler**

- **Boiler safety**

- **Danger of explosion**

Sludge and Scales

Water — Boiler wall — Loose precipitate suspended in water (sludge) — Heat — Hard adhering coating on inner walls of boiler (scale) — Heat

Disadvantages

- Bad conductor of heat (Wastage of Fuel)

- Reduces boiler efficiency

- Reduces the flow rate of water in boiler.

Prevention

- Use of water containing very low quantity of total dissolved solids.

- Frequently doing blow down operation.

Prevention of Scale formation

- **Use of softened water**

- **Phosphate conditioning**

- **Adding sodium aluminates**

- **Adding organic chemicals like tannin.**

- **Boiler feed water treatments**

- **Internal treatments- phosphate, calgon and colloidal conditioning.**

- **External treatment**

- **Ion exchange resins method**

- **Zeolite process**

- **numerical**

Phosphate Conditioning

- **Various phosphate are used depending on pH of boiler feed water**

- **Sodium phosphates converts Ca/Mg salt into corresponding phosphates**

- **Ca/Mg phosphates are easily removed by Blow down operation**

Scale $\xrightarrow{\text{chemical}}$ **Sludge**

Phosphate used	Nature of boiler Feed water
Na_3PO_4	Highly Acidic
NaH_2PO_4	Highly Alkaline
Na_2HPO_4	Weakly Alkaline

$$3\ CaSO_4 + 2\ Na_3PO_4 \longrightarrow Ca_3(PO_4)_2\downarrow + 3\ Na_2SO_4$$

Calgon Conditioning

- **Sodium hexametaphosphate forms soluble complex with Ca/Mg at pH 10**

$$Ca^{2+} + [Na_4P_6O_{18}]^{2-} \longrightarrow 2Na^+ + [CaNa_2P_6O_{18}]^{2-}$$
(Soluble complex)

Colloidal conditioning

- **Addition of tannin and agar agar**

- **Exceptional Ability to get coated over scale forming salts converting them into sludge**

- **Zeolite process**

- **Ion exchange method**

- **Synthetic ion exchange resins**

Zeolite

- **Naturally occurring hydrated aluminosilicates($Na_2O.Al_2O_3.$**

- **$xSiO_2.yH_2O$)**

- **Also known as Permutit or Molecular Sieves**

- **Porous Material**

- **Insoluble in water**

- **Works on Reversible Ion exchange Process**
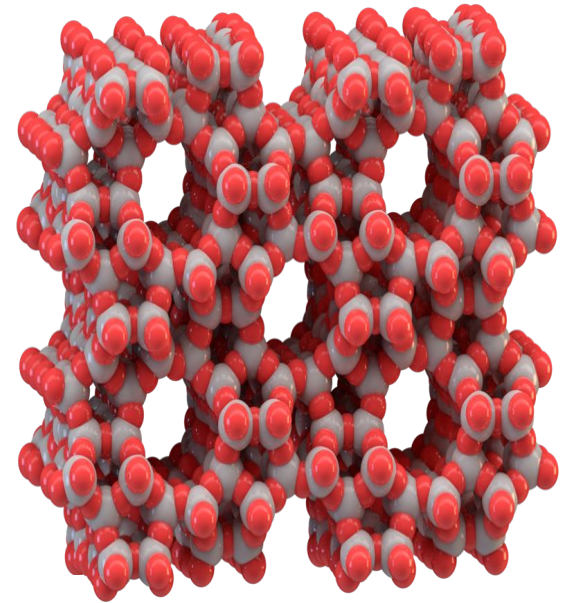
- Zeolites are crystalline microporous aluminosilicates with open 3D framework structures built of SiO_4 and AlO_4 tetrahedra linked to each other by sharing all the oxygen atoms to form regular intra-crystalline cavities and channels of molecular dimensions.

- Zeolite can trap Ca^{2+} , Mg^{2+} from hard water and release Na^+ ions into water
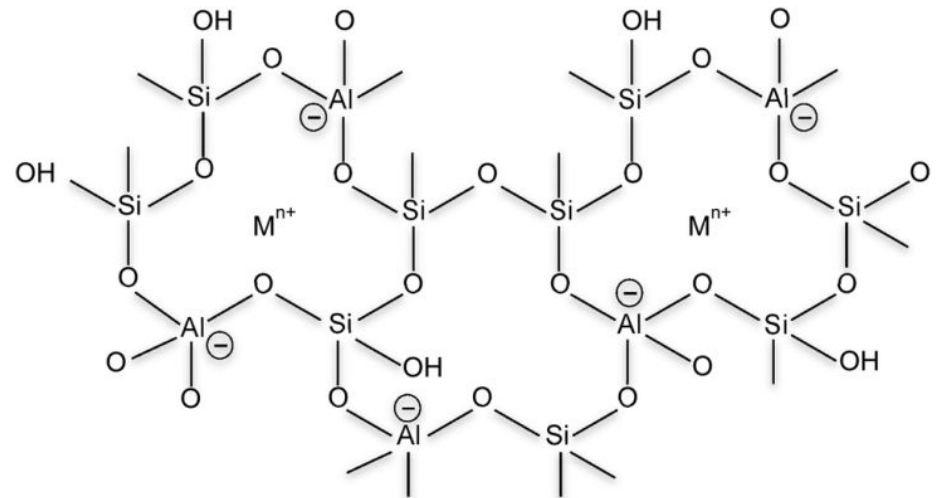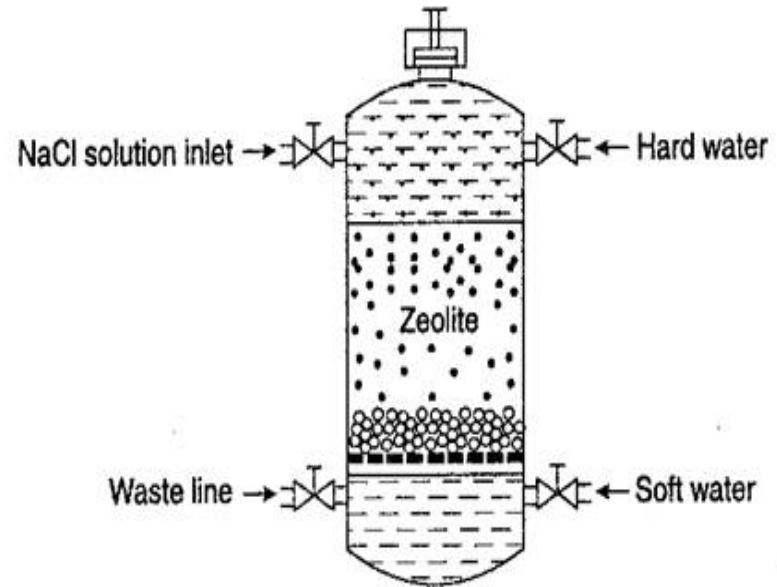
Process

- **Zeolites capture cations and releases equivalent Na$^+$ ions into water**

$$Na_2 Ze + Ca^{2+} \rightarrow CaZe + 2Na^+$$

Regeneration

- **Brine solution is used**

$$CaZe + 2NaCl \rightarrow Na_2 Ze + CaCl_2$$

- The effective concentration of sodium salt increases

- Mineral acid may disintegrate Zeolite bed

- Highly turbid water can not be treated

- Boiler feed Water with Fe^{+2} and Mn^{+2} can not be treated properly

- Capable of removing only Cations

- Hot water dissolves Zeolite

1. A zeolite bed was exhausted on softening of 4000 litre of water requires 10 litres of 15 % NaCl solution for regeneration. Calculate hardness of water sample.

2. A Zeolite softener was completely exhausted and was regenerated by passing 100 L of NaCl solution containing 120 g/L of NaCl. How many litres of water having hardness 500 ppm can be softened by this softener ?

- Solution to problem 1
- **Hardness of water = Amount of $CaCO_3$ (mg)**

-

- **Volume of water (L)**

- 15 g in 100 ml, so in 10 L NaCl is 1500 g.
- Amount of NaCl = 1500×10^3 mg

- No. of equivalents of $CaCO_3$ = No. of equivalents of NaCl
- Amount of $CaCO_3$ = $1.5 \times 10^6 \times 50$ = 1.28×10^6 mg

-                     58.5

-

- Hardness   = $\underline{1.28 \times 10^6}$ (mg)
-                  4000 L
-     = 320.6 ppm

- Solution to Problem 2
- Hardness of water= 500 ppm

- No. of equivalents of $CaCO_3$ = No. of equivalents of NaCl
- Amt of $CaCO_3$ = amt of NaCl (mg) x 50 (equivalent weight of $CaCO_3$)
- $\overline{\qquad\qquad\qquad\qquad}$ 58.5 (eq. wt. of NaCl)

- 120 g of NaCl in 1 L
- 1.2 x 10^7 mg of NaCl in 100 L

- Volume of water = 1.2 x 10^7 x 0.855 mg

- $\qquad\qquad\qquad\qquad$ 500
- $\qquad\qquad\qquad$ = 20512.8 L

Lecture - VII

- **Synthetic ion exchange resins method**

- **Desalination techniques**

- **Electrodialysis and Reverse osmosis**
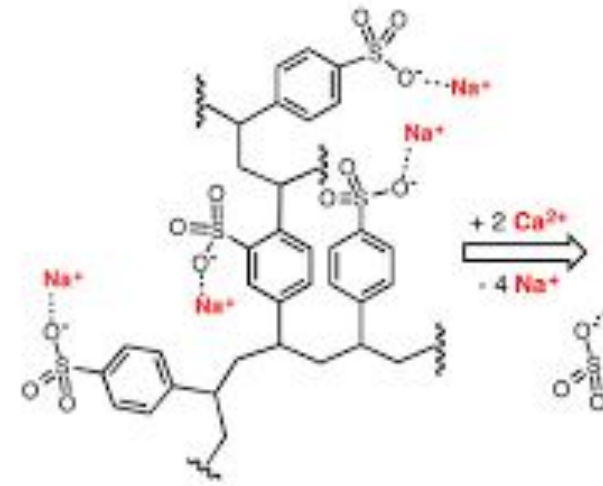
- **An ion-exchange resin or ion-exchange polymer is a polymer that contains positively or negatively charged sites that can attract an ion of opposite charge from a surrounding solution.**

- **Resins have either Acidic or Basic Functional group with loosely bound ions.**

- **Resins are used for water softening.**

Cation Exchange Resin (RH)

$$2RSO_3H + CaSO_4 \longrightarrow (RSO_3)_2Ca + H_2SO_4$$

- **Most commercial resins are made of polystyrene sulfonate.**

- **It is an insoluble matrix (or support structure) normally in the form of small (0.25–0.5 mm radius) microbeads, usually white or yellowish, fabricated from an organic polymer substrate. The beads are typically porous, <u>providing a large surface area on and inside them and the trapping of ions occurs along with the accompanying release of other ions, and thus the process is called ion exchange.</u>**

- **<u>Cation exchange resins exchange only cations</u>**

- **<u>Anion exchange resins exchange only anions</u>**

- **Net result is demineralised water**

- **Cation Exchange resin are**

- **regenerated by dilute HCl**

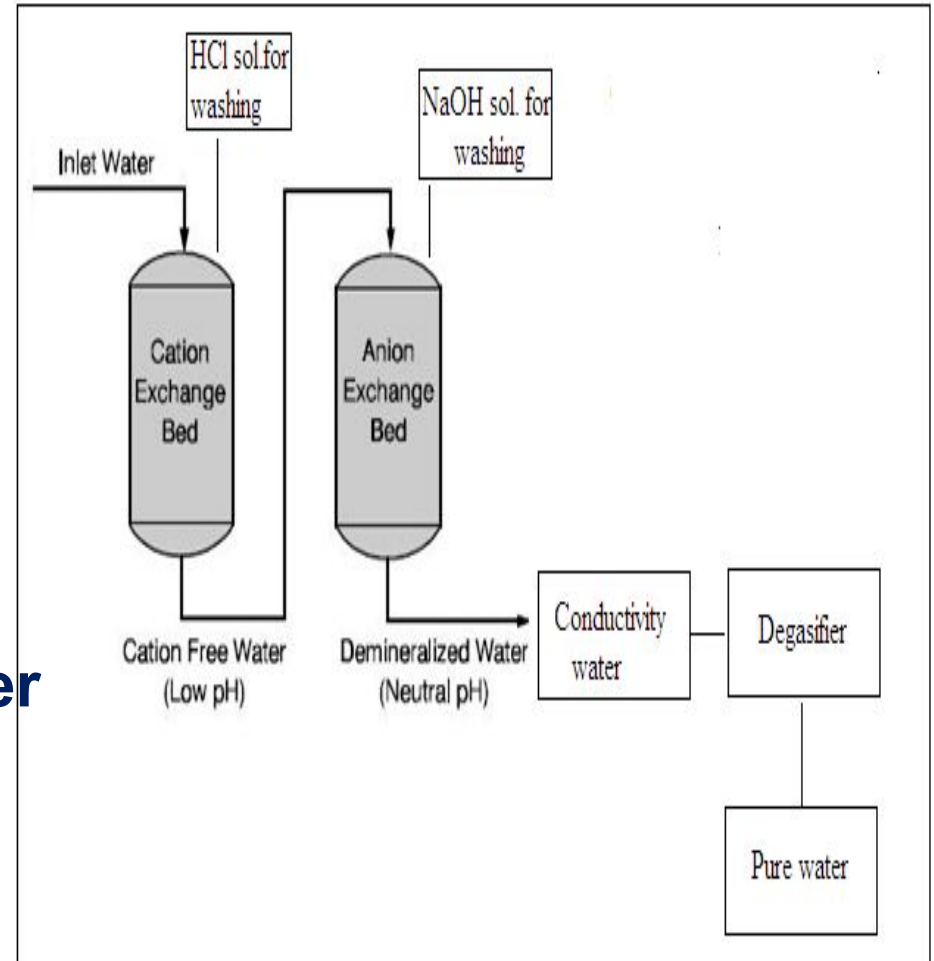- **Anion exchange resin**

- **are regenerated by dilute NaOH**
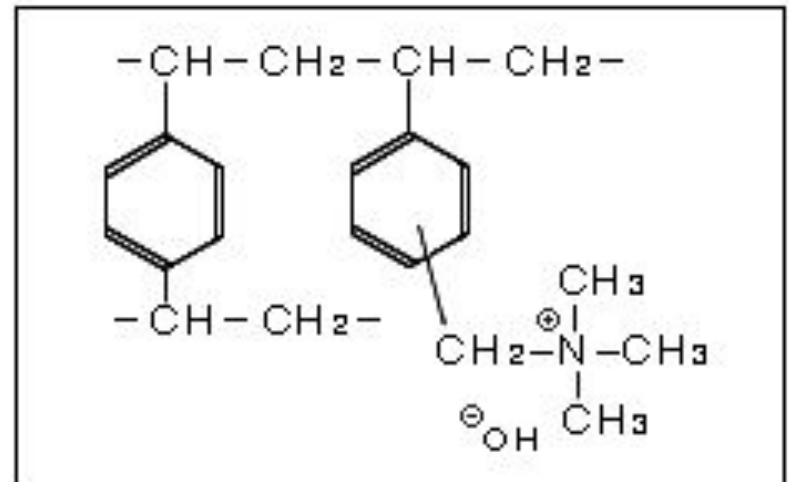
Anion Exchange Resin
$RCH_2NMe_3(OH) + SO_4^{2-} \rightleftharpoons RCH_2NMe_3SO_4 + OH^-$

- **Works well for variation of hardness of water**
- **Apparatus occupies small space**
- **Process is easy to operate**
- **Acidic or highly alkaline water can be treated effectively**

- The process of removing ionic pollutants from water using membranes under electrical potential difference is known as Electro dialysis.

- Ion selective membranes are used

- Cation selective membrane allow passage of cations only

- Anion Selective Membrane allow passage of anions only
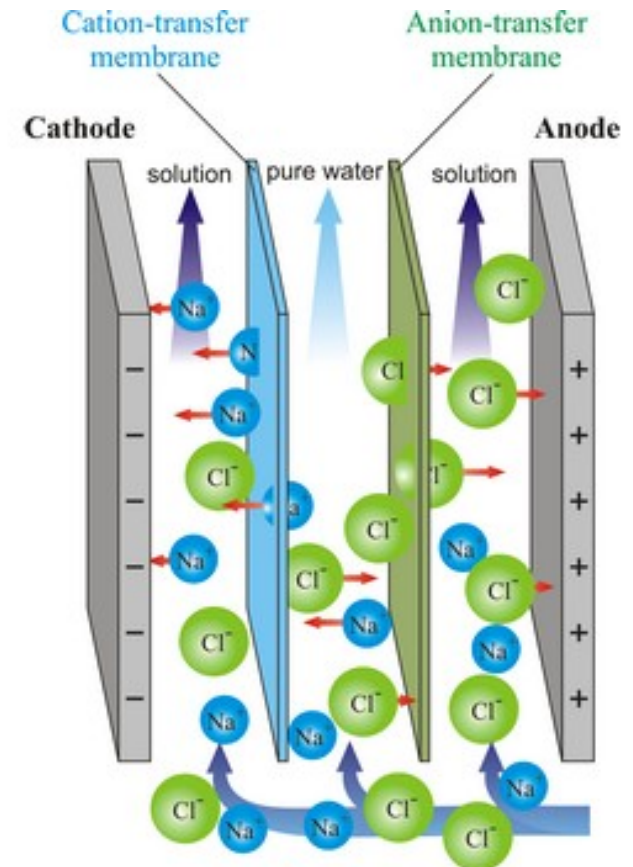
•Under the influence of electric field, ions migrate towards Electrode with opposite sign

•Concentrated and dilute solution are created in alternate compartments
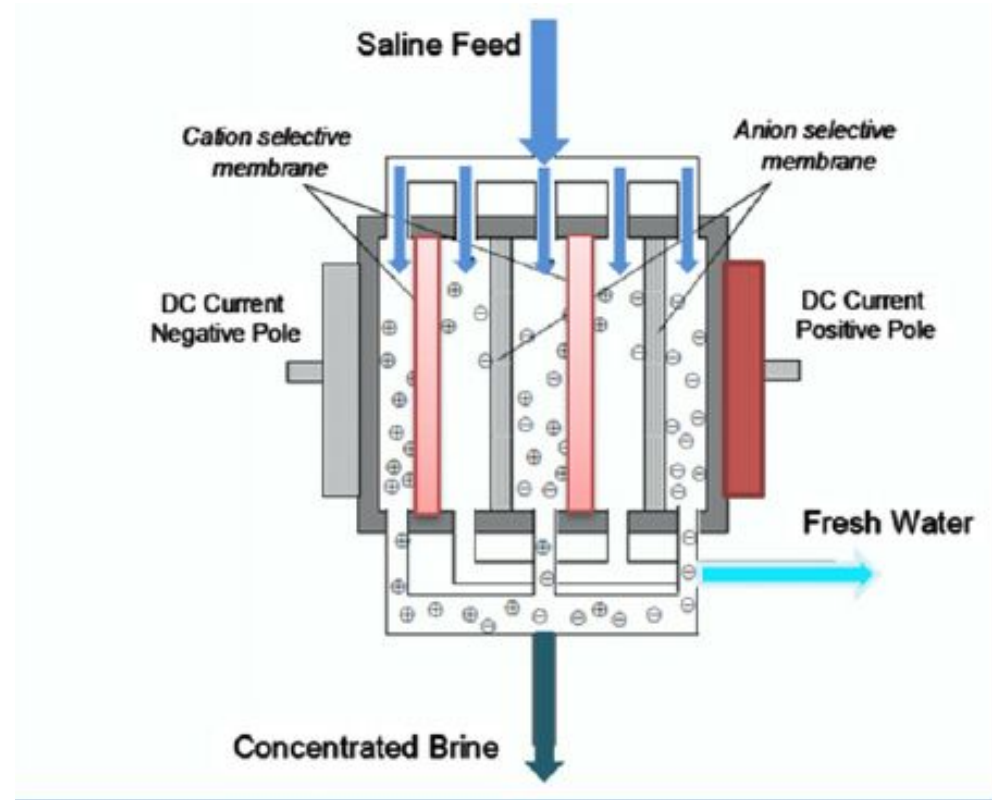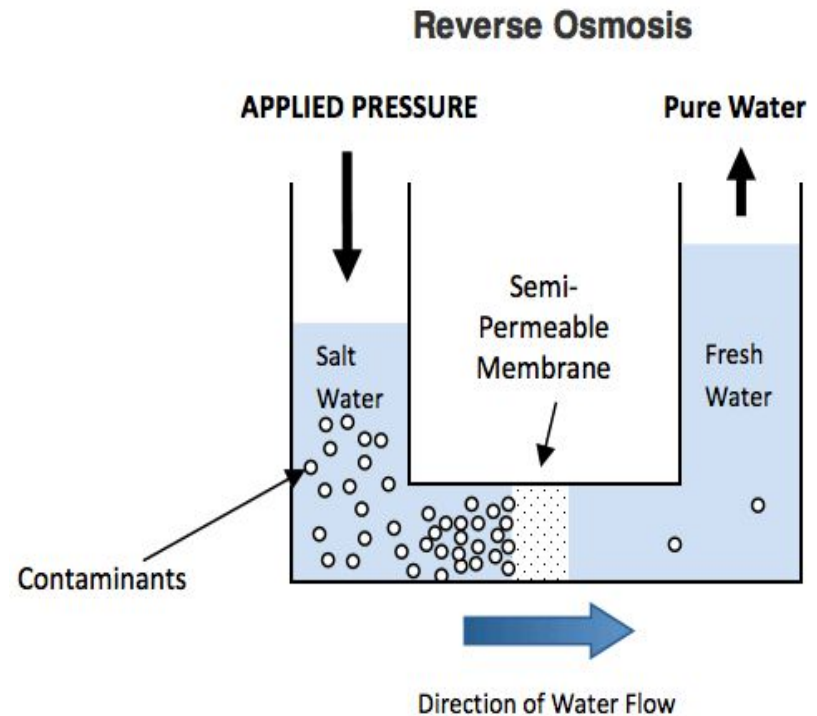
Anode and cathode reactions

- Reactions take place at each electrode.
- At the cathode,
- $2e^- + 2\,H_2O \rightarrow H_2\,(g) + 2\,OH^-$
- while at the anode,
- $H_2O \rightarrow 2\,H^+ + \frac{1}{2}\,O_2\,(g) + 2e^-$ or
- $2\,Cl^- \rightarrow Cl_2\,(g) + 2e^-$
- Small amounts of hydrogen gas are generated at the cathode and small amounts of either oxygen or chlorine gas (depending on composition of the E stream) at the anode.
- These gases are typically subsequently dissipated as the E stream effluent from each electrode compartment is combined to maintain a neutral pH and discharged or re-circulated to a separate E tank.
- Some researchers have proposed collection of hydrogen gas for use in energy production.

Applications of Electrodialysis

- In almost all practical electrodialysis processes, multiple electrodialysis cells are arranged into a configuration called an electrodialysis stack, with alternating anion and cation exchange membranes forming the multiple electrodialysis cells.

- Removal of ionic pollutants from treated industrial waste.

- Removal of salt from water.

- Removal of limited quantity of salts from sea water.

- **In RO process solvent molecules travel from high region of solute concentration to low solute concentration through semi-permeable membrane.**

- **External pressure is applied through high solute concentration compartment**

- **Most commonly used RO membranes are typically composed by a thin film composite membrane consisting of three layers: a polyester support web, a microporous polysulfone interlayer and an ultra thin polyamide barrier layer on the top surface.**

Reverse Osmosis

APPLIED PRESSURE   Pure Water

Semi-Permeable Membrane

Salt Water

Fresh Water

Contaminants

Direction of Water Flow

- **External applied pressure is greater than osmotic pressure (**Typical pressures for brackish water range from 1.6 to 2.6 MPa (225 to 376 psi). In the case of seawater, they range from 5.5 to 8 MPa (800 to 1,180 psi)).

- **Semi permeable membrane made up from polymeric materials like acrylics, polyamides, aramids.**

- **Membrane allow only passage of water molecules (Selective Porosity) and other impurities are rejected.**

- **Water gets separated from contaminants**

- Ionic, colloidal, non-ionic impurities removed from water.

- Pure water for high pressure boiler can be obtained.

- Used to obtain drinking mineral water.

- Simple to operate.

- Low cost process.

Numericals

- Q1. An exhausted zeolite softener was regenerated by passing 150 L of NaCl solution having strength of 150 g/L. If the hardness of water is 600 ppm, then calculate the total volume of water that can be softened by this zeolite.

- Amount of NaCl = 22500 g

- Amt of CaCO3 = 22500 x 0.855 g = 1.92 x 10^7 mg

- Volume = 1.92 x 10^7 mg/ 600 = 32051 L

- Q2. A sample of water on analysis, gave the following data:

- $Ca(HCO_3)_2$ = 10.5 ppm, $CaSO_4$ = 7.5 ppm

- $CaCl_2$ = 8.2 ppm, $Mg(NO_3)_2$ = 2.6 ppm

- Calculate the temporary and permanent hardness of the water sample.